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NASA CR-

DEVELOPMENT OF A THREE-DIMENSIONAL  
TIME-DEPENDENT FLOW FIELD MODEL

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Prepared under Contract No. NAS8-30380

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## ABSTRACT

A three-dimensional, time-dependent mathematical model to represent Mobile Bay was developed. The objective of this study was to develop computer programs which would numerically solve the appropriate conservation equations for predicting bay and estuary flow fields. The model will be most useful for analyzing the dispersion of sea water into fresh water and the transport of sediment. Also, the model serves as a useful tool for relating field and physical model data. The unique feature of this model is that it correctly accounts for momentum transfer in the governing flows; thereby, making it far more realistic than any previously devised. NASA's ERTS and Skylab programs resulted in high quality photographs of Mobile Bay. U.S. Army Corps of Engineers have also studied this bay extensively. All these data have been reviewed for comparison to this mathematical model.

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## NOMENCLATURE

### English Letters:

c	heat capacity
$C_1, C_2$	stretching constants
E	sum of specific internal, kinetic, and potential energy
g	gravity force
h	free surface height
I	unit tensor
J	diffusion - flux with respect to number-average velocity
K	diffusion - flux with respect to mass-average velocity
M	molecular mass (or weight)
N	molarity
P	pressure
q	heat-flux vector
$q_R$	heat-flux vector due to radiation
S	concentration of salt-water in a binary mixture of fresh water salt-water
t	time
T	temperature
U	number-average velocity
V	mass-average velocity
x	} Cartesian coordinates
y	
z	
Y	transformed y coordinate

### Greek Letters:

$\mu$	viscosity
$\rho$	density
$\tau$	shear-stress tensor
$\Omega$	earth's rotation vector
$\Phi$	viscous generation of heat

### Subscripts:

f	fresh-water property
s	sea-water property
x	} component of property in specified direction
y	
z	

### Mathematical:

-	vector
=	2nd order tensor
$\nabla$	del operator
$\Sigma$	summation
$\partial$	partial
$D( )/Dt$	substantial derivative with respect to number-average velocity
	variable preceding symbol is evaluated at the location which follows the symbol

## INTRODUCTION

This report describes the development of a three-dimensional, time-dependent flow field model to represent Mobile Bay. This model is a mathematical representation of the appropriate conservation equations which has been evaluated with a digital computer. Since all important physical phenomena cannot be mathematically modeled in a definitive fashion, the errors introduced by approximations made to make the model tractable must be evaluated. Therefore, the model was prepared specifically to represent Mobile Bay.

Mobile Bay is not only a commercially important but also a technically interesting bay to study. The bay is connected by a tidal inlet to the Gulf of Mexico, thereby forming a region in which sea water is measurably diluted with land water drainage. Such a region is called an estuary. The drainage occurs by several large rivers discharging both water and sediment into the bay. A ship channel extends from end-to-end of the bay; the channel is dredged and maintained by the Corps of Engineers. The bay is shallow and therefore greatly affected by prevailing winds.

All estuaries are so complex that any mathematical model which may currently be implemented on a computer will contain certain simplifications to make a solution of the model tractable. These simplifications are so severe that once the model is developed it must be tested to prove that it is a valid representation of the estuary. Ideally, one would like to have sufficient experimental data from direct field measurements to test the model. Usually, sufficient data are not available. Even when they are, initial attempts at modeling will invariably show some discrepancy, then the model will have to be "improved".

Methods of making such improvements are not, usually, obvious, because the very complexity of estuaries defies establishing cause and effect phenomena. Results from physical model studies contribute much more to this stage of mathematical model development. This is due to the fact that physical model experiments can be designed to emphasize specific study of select phenomena, i.e. complicating factors can simply be eliminated in these studies. Use of only "real world" field data cannot be so utilized because our environment cannot be so controlled. Of course, physical model data is also often used without collaborating field or mathematical model data.

These general comments concerning the interactions of field, mathematical model, and physical model data precisely describe our current state-of-knowledge of Mobile Bay. Several attempts have been made to measure the flow properties within the bay; the most complete and recent study was performed by the Corps of Engineers to provide verification data for a physical model study which is being conducted, also by the Corps at Vicksburg, Mississippi. The purpose of the physical model experiments is to study the impact of opening another ship channel within Mobile Bay. Photographic data from NASA are also available.

This report summarizes the Corps of Engineers data pertinent to Mobile Bay, describes the mathematical model which has been developed to describe Mobile Bay, and compares data from all three sources.

### SUMMARY OF FIELD DATA

Results from several field studies of Mobile Bay have been reported (1, 2). Although these reports present many measurements descriptive of the flow-field, there is not sufficient information at any given instant of time to constitute adequate boundary conditions and check-points to be compared to a mathematical model. An adequate experiment was performed by the Mobile District Corps of Engineers for verifying the physical model study which will be described in the next section of this report.

These verification measurements (3) consisted of flow and tide level data through the four major river inlets to the north and the two major passes in the south for a complete tidal cycle. At the passes, vertical salinity profile data were also collected. Cross-sectional areas for the inlet and outlets were determined. Finally, tide, velocity, and salinity vertical-profile data were also taken at select stations within the bay. These regions are shown in Figure 1.

There are other rivers which were not measured during this study, presumably because there is little flow through them. However, what was measured corresponds exactly with the streams which are included in the physical model. Also, no data on winds or on flow into or out of the northern marshes are given. There is an airport weather station nearby from which some wind data may be obtained.

The four river inlets were taken to be where the highway crosses the north end of the bay. These inlets and cross-sectional areas were the: Mobile, 2,120 sq. m (22,810 sq. ft.); Tensaw, 2,850 sq. m (30,660 sq. ft.); Apalachee, 2,013 sq. m (21,660 sq. ft.); and Blakeley, 2,499 sq. m (26,880 sq. ft.). These rivers are shown in Figure 2. Notice that part of the flow from the upper Mobile River passes into the bay through the Tensaw inlet, and that all of the flow from the upper Tensaw enters through the Tensaw, Apalachee, and Blakeley.

The mouth of Mobile Bay is 30,265 sq. m (325,600 sq. ft.) in cross-section. The pass connecting Mobile Bay to the Mississippi sound between Cedar Point and Dauphin Island is 6,144 sq. m (66,100 sq. ft.) in cross-section. All cross-sections are the area between mean-sea level and the bottom. The bottom location changes significantly with time, probably because of sediment deposition.

The previously mentioned data are available for further study. Only two points need further comment at this time. Low tide at

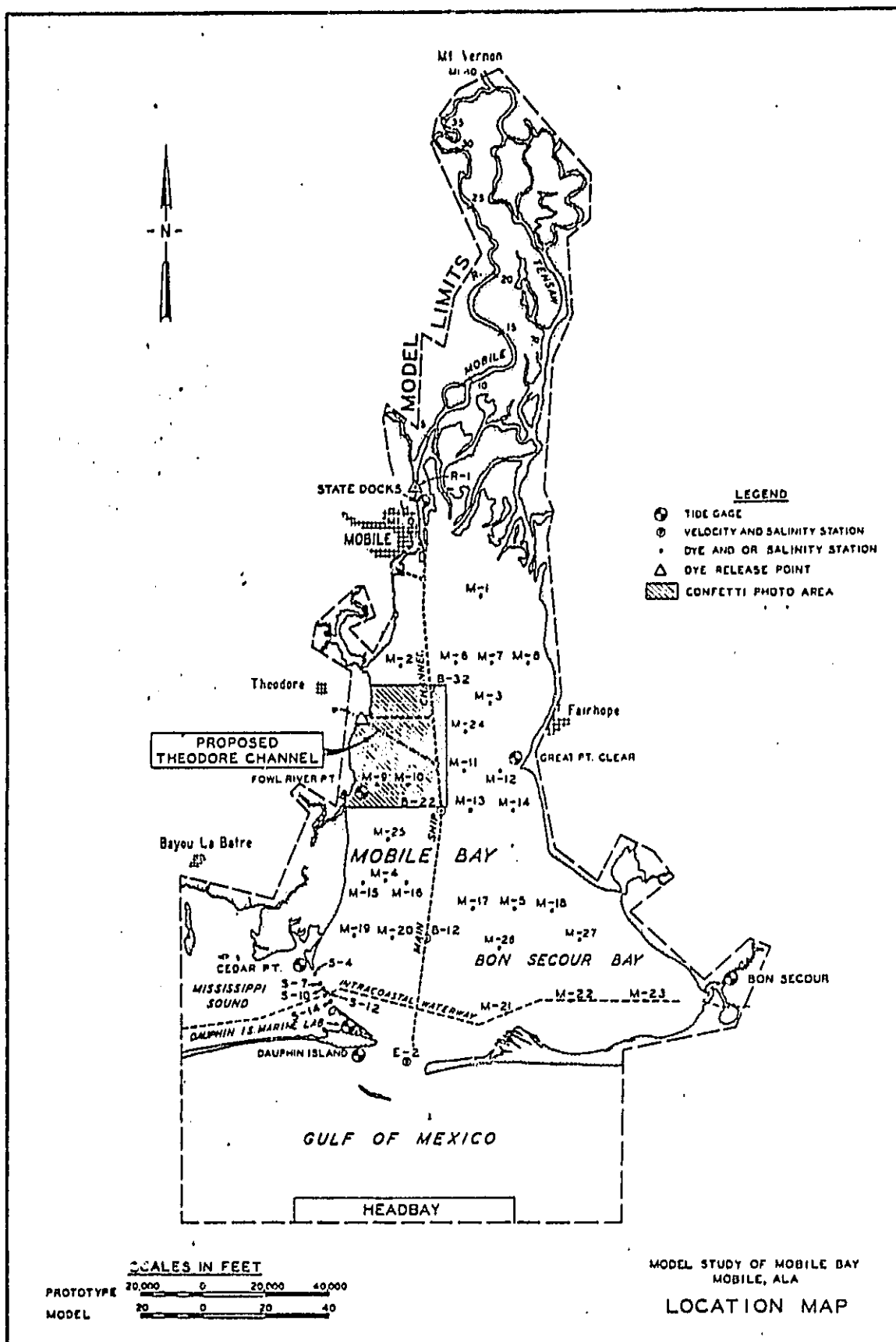


Figure 1. Mobile Bay



Mobile Point occurs some 4 hours before low tide at the Mobile River inlet; high tide about 2.5 hours before. This demonstrates that there are significant tidal phenomena within the bay.

The second point is that the high tide causes flow reversal in the river inlets at the north end of the bay. This implies that one would have to go up-stream before the rivers would be discharging, i.e. the bay, marshes, and lower river channels are filling with water on a rising tide. This fact complicates the mathematical specification of boundary conditions at the northern end of the bay. These marsh regions are clearly discernible in the ERTS IR photograph shown in Figure 3. The dark regions in the river valleys north of the bay are the marshes. Notice that these marshes do not extend down either side of the bay.

Figure 4 is a companion picture to Figure 3, but it was taken at visual wavelength. Although quantitative data cannot be obtained from such photographs, the long distances over which the river plumes retain their shape and the dead water region in Bon Secour are clearly evident. Similar data in true color from Skylab photographs are also available.

#### PHYSICAL MODEL DATA

In order to estimate possible effects caused by building a new ship channel, to be named Theodore Channel, the Corps of Engineers have performed physical model studies of Mobile Bay. First a set of base data for the Bay as it now exists was collected, then the new channel and several possible new islands which serve as spoilage banks were modeled and studied. The base data are of interest to this study; such data were made available to these investigators by the Mobile District Office of the Corps (4).

The region of the Bay which was physically modeled is shown in Figure 1. Salinities and velocities at the numbered surface locations during a tide cycle are reported for the "surface" and "bottom" elevations. The Mobile and Tensaw Rivers flows were metered and reported, presumably well up-stream of the northern reaches of the Bay. Note this does not correspond to the location where the field data are reported. The river volumetric flow rates were reported as (cubic feet/second) of prototype flow, and tide levels in (ft) of prototype surface elevation. The scaling laws used for such unit conversions are not presently known to these investigators. Note also should be made that "turbulence strips" were used in these model studies. Therefore, the physical model data will be considered as its representation of the actual Bay, which is how the modelers intended it should be used.

Tide data at the north, south, and middle points of the Bay are shown in Figure 5. Note that high tide occurs about 3 hours later at the state docks location than at Dauphin Island. This difference between physical model and field data is thought to be significant.



Figure 3. IR Photograph of Mobile Bay from NASA's ERTS Program

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OF POOR QUALITY

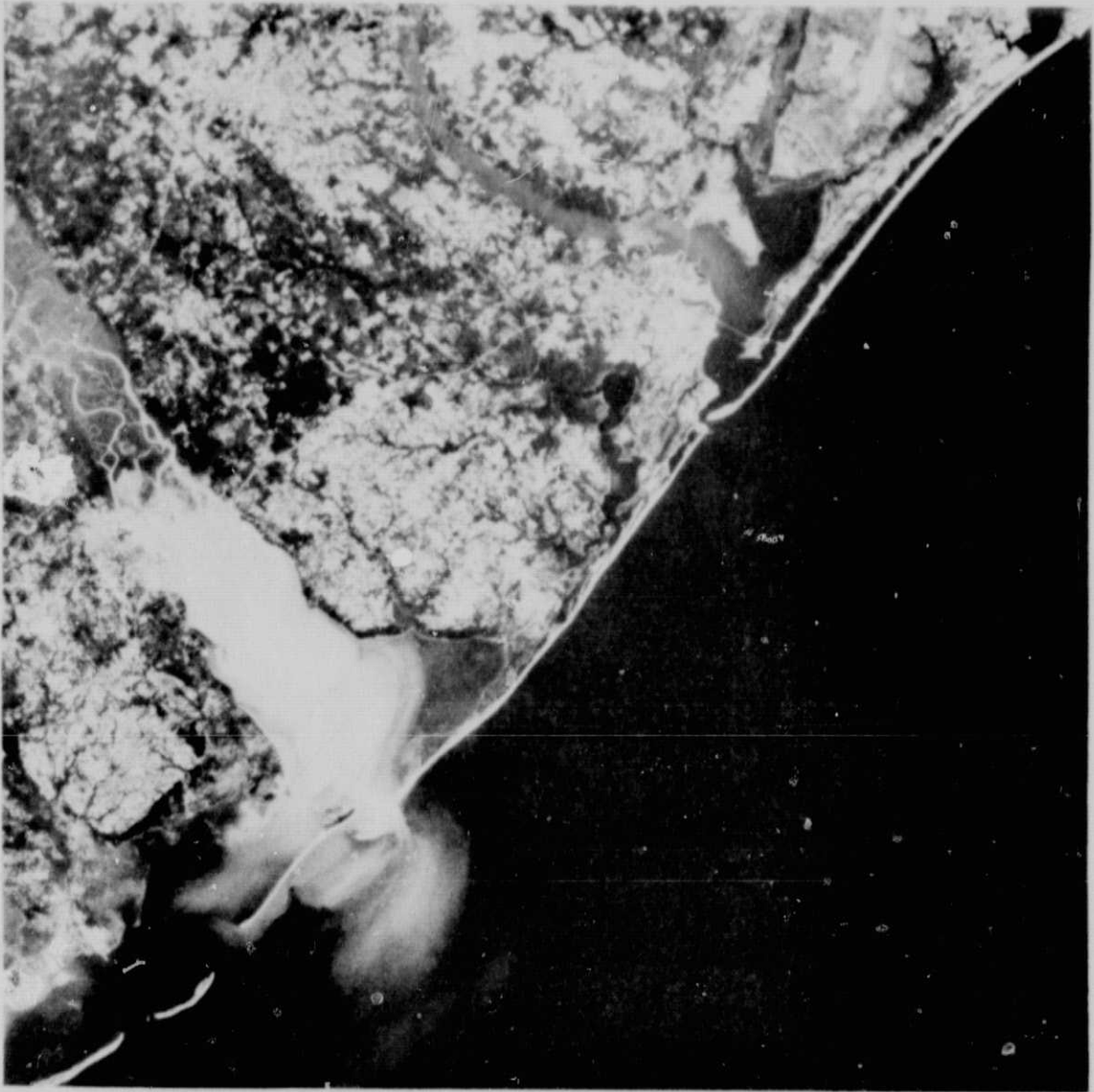


Figure 4. Black and White Photograph of Mobile Bay from  
NASA's ERTS Program



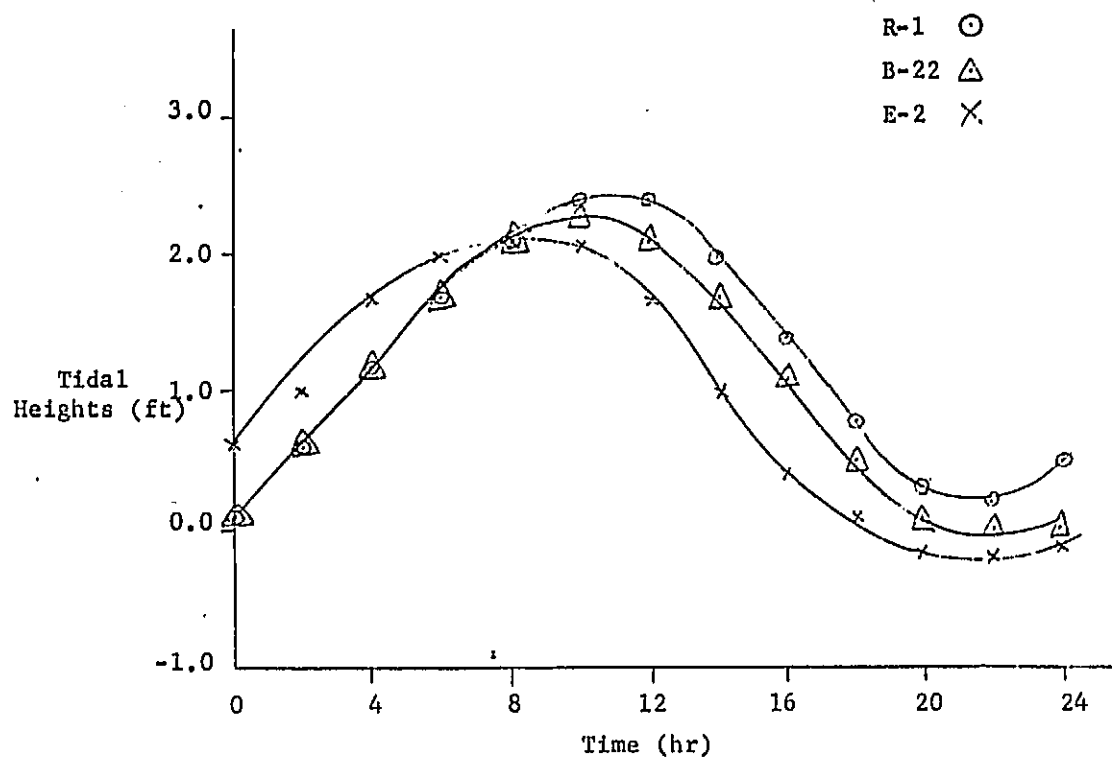


Figure 5. Tide Heights at Various Bay Stations

All velocities are reported as north or south velocity components only. Data are available at many more model stations than field stations. Interior stations at B-12 and B-32 are the only two field stations.

### THE MATHEMATICAL MODEL

The philosophy of developing and using a mathematical model is that a certain set of equations represents the phenomena of interest in the region of interest and that these equations may be solved for a particular set of auxiliary conditions. The solution would represent the behavior that one wishes to predict, and the auxiliary conditions and/or specified parameters in the equations would represent alternatives that one wishes to either understand or control.

Any and all errors which might be in the model would manifest themselves as inaccuracies in the flow description, hence, calculated results should be verified before a model is used. All known information concerning the flow region of interest should be considered to establish this verification. It is impossible to either completely measure or model a large, complex flow-field; therefore, model development and verification proceed in a "hand-over-fist" fashion. That is, as more is learned of the flow better predictions can be made, and as better predictions are made the more important regions of the flow can be identified for further field study.

Any model study is bounded by the desire for completeness and the necessity for economy; therefore, a modeling scheme which attempts to optimize this balance was developed. Since flow within the ship channel is believed to exert a dominating influence on the flow of sea water into the bay and on the sediment deposition trends within the bay, a three-dimensional, time dependent flow field model was deemed essential to describe the type flow found in Mobile Bay.

### Model Development

All solutions to fluid mechanics problems are based on conservation principles. These principles, usually expressed as a conservation of mass, momentum and energy, are presented in most standard texts of fluid mechanics for single-component flows. The phenomena of interest is that involving the relative motion and the mixing of fresh and saline water. Sediment transport is also of interest, but its study will be postponed to a future time.

Because the fluid in the mixing region may have two components some care must be exercised to insure that the most useful form of the pertinent conservation laws is determined. Also, it is fruitful to consider and compare experimental results and analytical methods which arise from studies of heated water discharges. The relationship between the mass density of fresh water and sea water

and various mixtures of the same may be represented as a linear function of the amount of salt in the mixture, but the number of moles (or particles) in a unit volume is a constant. This means that any diffusion which occurs must behave as a replacement process, i.e. a molecule of "salt-water" replaces a molecule of fresh water. Furthermore, by introducing a fictitious molecular weight for salt water, the fluid may be described as a binary mixture of fresh water molecules and salt-water molecules. This behaviour of the number density allows one to specify the condition for incompressible flow by stating that the substantial derivative of the number density of fluid particles with respect to a number average velocity is zero, or that the divergence of the number average velocity is zero for an isothermal fluid. A similar relationship for the effect of modest temperature changes on the density of water exists. Now all the conservation laws may be stated.

Very generally, the conservation of mass equation states that the amount of mass accumulated in a given volume is equal to the difference between the mass convected out of the volume and the mass convected in. For multicomponent fluids, the net flux of mass into the volume by diffusion must also be considered.

The conservation of momentum is derived from Newton's second law of motion. Expressed for fluids, this states that the rate of change of momentum of the fluid in a given volume is equal to the summation of the vector forces acting on the fluid. Pertinent forces may consist of pressure forces, shearing stresses, and gravity forces. An apparent force known as the Coriolis force may also be included when the equation is expressed in a coordinate system which is moving relative to an inertially fixed system. Unfortunately, the momentum and energy equations are cumbersome when written in terms of the number average velocity; therefore, both the number average velocity and the mass average velocity will be used in formulating the conservation laws.

The conservation of energy equation results from applying the first law of thermodynamics to the moving fluid; it states that the rate of increase in total energy is equal to the sum of the rate of work done on the fluid and the rate of heat added from external sources. The total energy of a given volume of fluid consists of three types: internal energy which may be expressed as a function of the temperature, kinetic energy due to velocity of the fluid, and potential energy which is a function of elevation of the particles of fluid. The rate of work done to the fluid results from pressure forces, gravity forces, and viscous and turbulent shearing forces.

The energy equation reduces to a trivial form for incompressible, isothermal flows when velocities are such that there is little heat generated by viscous dissipation. Thus, the conservation of mass and momentum equations produce an independent and complete set.

In addition to the general conservation equations, an equation of state is required to express density as a function of composition

and temperature. For liquids, density and temperature are usually independent of pressure, i.e. incompressible.

The conservation laws and equations are summarized in Table 1. Note that interpretation of the transport coefficients as either molecular or eddy values allows the stated equations to be used for both laminar and turbulent flows. The complete conservation equations just described represent a complex set of second order, nonlinear partial differential equations. Even so, these equations do not precisely describe certain types of flow. This inexactness is due to lack of properly specifying specific terms of these equations as certainly the basic laws must be observed. It is an easy matter to indicate turbulent transport with a coefficient; specifying the local value of such a coefficient is another matter entirely. Furthermore, the microscopic interaction of the fluid particles and solid material (i.e. sediment) is not completely known, and is not, therefore, represented by the equations in Table 1.

The actual solution of these equations will use an approximation presented by Frank-Kamenetskii (Ref 5) and utilized by Daly and Pracht (Ref 6) which states that negligible differences result from using the number average velocity instead of the mass average velocity in the conservation of momentum and energy equations. This then yields a set of equations with only one velocity.

Another approximation suggested by Yih (Ref. 7) is quite useful in simplifying the conservation equations. Yih recognizes that the coefficient of expansion  $\partial\rho/\partial T$  is very small compared with unity for most liquids and, through a perturbation analysis, shows that  $\nabla \cdot \bar{U} \approx 0$  when the range of temperatures are small relative to the mean absolute temperature. The implication of this assumption is that the volume dilation due to thermal expansion is negligible. This approximation is analogous to that involving the use of number-average velocity to simplify the solution of the two-component system of equations.

Before the equations are solved, one must choose a suitable coordinate system. A Cartesian system was chosen.

The resulting equations, including the approximations described above, which apply directly to non-isothermal, two-component fluid motions for the case of interest are may be solved by the method reported herein. The transport co-efficients may differ in each of the spatial directions. It should also be noted that the radiative heat flux vector  $q_r$  of the energy equation need only be considered at the surface of the fluid; hence, it could be justly considered as a boundary condition. Furthermore, the two most common situations arise when the fluid is one-component ( $S = 0$ ) or is isothermal ( $T = \text{constant}$ ); seldom must both variations be considered simultaneously.

Although the species continuity equation of Table 1 is written for the salt concentration  $S$ , it is equally applicable for the

Table 1. General Conservation Laws for Modeling  
Bays and Estuaries

Overall Continuity Equation.

$$\frac{\partial \rho}{\partial t} + \bar{U} \cdot \nabla \rho + \rho(\nabla \cdot \bar{U}) = \rho \nabla \cdot (\bar{U} - \bar{V}) \quad (1)$$

Approximate Equation of State.

$$\rho = \rho_f + \left( \frac{\partial \rho}{\partial S} \right)_T S + \left( \frac{\partial \rho}{\partial T} \right)_S (T - T_o) \quad (2)$$

Diffusive Behavior.

$$\rho \nabla \cdot (\bar{U} - \bar{V}) = \left( \frac{\partial \rho}{\partial S} \right)_T \left( \frac{\partial S}{\partial t} + \bar{U} \cdot \nabla S \right) \quad (3)$$

Compressive Behavior.

$$\rho(\nabla \cdot \bar{U}) = - \left( \frac{\partial \rho}{\partial T} \right)_S \left( \frac{\partial T}{\partial t} + \bar{U} \cdot \nabla T \right) \quad (4)$$

Momentum Equation.

$$\frac{\partial(\rho \bar{V})}{\partial t} + \bar{V} \cdot (\nabla \rho \bar{V}) = - \nabla P + \nabla \cdot \mu \nabla \bar{V} - \rho \bar{g} - \rho(2\Omega \times \bar{V}) \quad (5)$$

Energy Equation.

$$\frac{\partial(\rho E)}{\partial t} + \nabla \cdot (\rho E \bar{V}) + \nabla \cdot \bar{q} + \nabla \cdot (\bar{\tau} - \bar{I}P) \cdot \bar{V} - \Sigma \bar{g}_i \cdot \bar{J}_i = 0 \quad (6)$$

Relationship Between Mass-Average and Number-Average Velocity.

$$\bar{U} - \bar{V} = \bar{J}_s / [S + (M_s \rho) / (M_f - M_s)] \quad (7)$$

Relationship Between Mass Flux Vector and Molar Flux Vector.

$$\bar{J}_s = \bar{K}_s [1 + (S/\rho)(M_f - M_s)/M_s] \quad (8)$$

conservation of any chemical or biological species with the inclusion of a rate of generation (or degeneration) term. These equations could then be applied to the dispersion of any pollutant discharged into a river or bay. Should the species have a negligible effect upon the density as is often the case, then the species continuity equation could be decoupled from the other conservation equations. For this case, the flow field could be computed and the resulting velocities used to compute the advection, diffusion and generation of the species. For cases where the density is affected by the concentration of the species, this decoupling is not applicable. The species continuity equation should then be solved simultaneously with the other conservation equations.

To model Mobile Bay, the flow is considered isothermal and to be a binary mixture of salt and water; therefore, the equations given in Table 2 apply. Furthermore, the viscous terms in the z-momentum equation were also neglected, since an order of magnitude analysis showed them to be two orders lower than the pressure and gravity terms in this equation.

#### Solution Technique

The set of equations as presented in Table 2 is sufficient to describe all the dependent variables for a given set of eddy coefficients, but the equations are in a form for which there is no known analytical solution. These equations will be approximated by a set of finite-difference equations and solved by using a time-dependent technique. Before writing the equations in finite-difference form, a stretching transformation that will create a more efficient use of grid points is suggested. For example, by letting

$$y = \frac{1}{C_1} \tan \frac{Y}{C_2} \quad (15)$$

where  $C_1$  and  $C_2$  are arbitrary constants, the equations of Table 2 can be expressed as functions of  $Y$  instead of  $y$ . The implications of this transformation can be more easily understood by rewriting it as

$$Y = C_2 \tan^{-1} (C_1 y) \quad (16)$$

When  $y = 0$ , then  $Y = 0$ . Grid planes located at even increments of  $\Delta Y$  will produce ever-increasing increments of  $\Delta y$ . This transformation will increase resolution where it is most needed and make specifying boundary conditions less critical.

The philosophy of using this numerical procedure is to begin with a set of initial values of the dependent variables at all grid intersections and allow the flow field to adjust asymptotically until all the conservation equations and boundary conditions are satisfied. The final result will be a steady-state flow field. Naturally, the better the estimate for the initial data, the more rapid the convergence, but even a crude guess, one conveniently

Table 2. Specific Conservation Laws for the Proposed Mobile Bay Model

Species Continuity Equation.

$$\frac{DS}{Dt} = D_x \frac{\partial^2 S}{\partial x^2} + D_y \frac{\partial^2 S}{\partial y^2} + D_z \frac{\partial^2 S}{\partial z^2} \quad (9)$$

Equation of State.

$$\rho = \rho_f + \left( \frac{\partial \rho}{\partial S} \right)_T S \quad (10)$$

Compressive Behavior.

$$\nabla \cdot \bar{U} = \frac{\partial U_x}{\partial x} + \frac{\partial U_y}{\partial y} + \frac{\partial U_z}{\partial z} = 0 \quad (11)$$

Momentum Equation.

$$\begin{aligned} \frac{D(\rho U_x)}{Dt} = & - \frac{\partial P}{\partial x} + \frac{\partial}{\partial x} \left( \mu_x \frac{\partial U_x}{\partial x} \right) + \frac{\partial}{\partial y} \left( \mu_y \frac{\partial U_x}{\partial y} \right) + \frac{\partial}{\partial z} \left( \mu_z \frac{\partial U_x}{\partial z} \right) \\ & + 2\rho\Omega_z U_y \end{aligned} \quad (12)$$

$$\begin{aligned} \frac{D(\rho U_y)}{Dt} = & - \frac{\partial P}{\partial y} + \frac{\partial}{\partial x} \left( \mu_x \frac{\partial U_y}{\partial x} \right) + \frac{\partial}{\partial y} \left( \mu_y \frac{\partial U_y}{\partial y} \right) + \frac{\partial}{\partial z} \left( \mu_z \frac{\partial U_y}{\partial z} \right) \\ & - 2\rho\Omega_z U_x \end{aligned} \quad (13)$$

$$\frac{D(\rho U_z)}{Dt} = - \frac{\partial P}{\partial z} - \rho g_z \quad (14)$$

specified, is sufficient. The boundary conditions will then be replaced with conditions which depend on time, and the asymptotic solution will become an initial condition. An unsteady solution will result from further calculations. An efficient method for specifying initial conditions when making a series of calculations with similar geometry is to store the results of one run on tape and recall these data as initial conditions for the next run. Experience has shown that this can reduce computation times for subsequent runs by a factor of four.

The numerical technique for calculating the dependent variables actually involves a sequence of calculations for each time step. The first step of the sequence involves computing new values of  $U_x$ ,  $U_y$ , and  $S$  (and  $T$ , when needed) at each grid intersection by stepping forward in time by  $\Delta t$ . This is best explained by considering the following truncated Taylor series:

$$U_x\{n+1,i,j,k\} = U_x\{n,i,j,k\} + \frac{\partial U_x}{\partial t}\{n,i,j,k\} \Delta t \quad (17)$$

The braces indicate functionality,  $n$  is the index of the time step, and  $i,j,k$  indicate specific  $x,Y$ , and  $z$  grid planes, respectively. A finite difference approximation to the transformed right-hand side of the  $x$ -momentum equation of Table 2 can be substituted for  $\partial U_x / \partial t$ . Similar expressions can be written for  $U_y$  and  $S$  or  $T$ .

The maximum possible time step for this type of numerical scheme is approximately given by the Courant-Friedricks-Lewy (CFL) condition, but in actuality this maximum time step is seldom obtained. There are various procedures for increasing the stable time step of a truncated Taylor's series such as the one shown, but they all pay a penalty in computation time per step and/or computer core storage. A method which has proven quite useful to these authors is best explained by considering another truncated Taylor series:

$$U_x\{n+1,i,j,k\} = U_x\{n,i,j,k\} + \left[ \frac{\partial U_x}{\partial t}\{n,i,j,k\} \right] \Delta t + \left[ \frac{\partial^2 U_x}{\partial t^2}\{n,i,j,k\} \right] \frac{(\Delta t)^2}{2} \quad (18)$$

The braces indicate functionality,  $n$  is the index of the time step, and  $i,j,k$  indicate specific  $x,Y$ , and  $z$  grid planes, respectively. When  $(\partial^2 U_x) / (\partial t^2)$  is approximated by a forward difference as a function of  $(\partial U_x) / (\partial t)$ , one has

$$U_x\{n+1,i,j,k\} = U_x\{n,i,j,k\} + \left[ \frac{\partial U_x}{\partial t}\{n,i,j,k\} + \frac{\partial U_x}{\partial t}\{n+1,i,j,k\} \right] \frac{\Delta t}{2} \quad (19)$$



The  $(\partial U_x)/(\partial t) \{n, i, j, k\}$  can easily be computed from a finite-difference approximation to Equation 12. Upwind differencing was used for the convective terms. For the case of positive  $U_x$  and negative  $U_y$  and  $U_z$  components of velocity at grid point  $i, j, k$ , the finite difference approximation of Equation 12 becomes

$$\begin{aligned} \frac{\partial U_x}{\partial t} \{n, i, j, k\} = & - \left[ \frac{1}{\Delta x} (U_x^2 \{n, i+1, j, k\} - U_x^2 \{n, i, j, k\}) \right. \\ & - \frac{0.5}{\rho \{n, i, j, k\}} [P \{n, i+1, j, i\} - P \{n, i-1, j, k\}] \\ & + \frac{Y \{j\}}{\Delta y} (U_x \{n, i, j, k\} U_y \{n, i, j, k\} - U_x \{n, i, j-1, k\} U_y \{n, i, j-1, k\}) \\ & + \frac{1}{\Delta z} (U_x \{n, i, j, k\} U_z \{n, i, j, k\} - U_x \{n, i, j, k-1\} U_z \{n, i, j, k-1\}) \\ & + \epsilon_H \left[ \frac{1}{(\Delta x)^2} (U_x \{n, i+1, j, k\} - 2U_x \{n, i, j, k\} + U_x \{n, i-1, j, k\}) \right. \\ & + \frac{Y' \{j\}}{\Delta y} (U_x \{n, i, j+1, k\} - 2U_x \{n, i, j, k\} + U_x \{n, i, j-1, k\}) \\ & + \frac{Y'' \{j\}}{2\Delta y} (U_x \{n, i, j+1, k\} - U_x \{n, i, j-1, k\}) \\ & \left. + \epsilon_z \left[ \frac{1}{(\Delta z)^2} (U_x \{n, i, j, k+1\} - 2U_x \{n, i, j, k\} + U_x \{n, i, j, k-1\}) \right] \right] \quad (20) \end{aligned}$$

where

$$Y' \{j\} = \frac{dY}{dy} \{j\}$$

and

$$Y'' \{j\} = \frac{d^2 Y}{dy^2} \{j\}$$

Computing  $\partial U_x / \partial t \{n+1, i, j, k\}$  is more difficult because dependent variables at time  $n+1$  are required but are not known. For this reason, solutions of Equation 19 usually fall into two classes: the implicit schemes which involve matrix inversion, and two-step schemes which estimate provisional values at time step  $n+1$ . From a practical stand-point, the primary reason for including  $(\partial^2 U_x) / (\partial t^2)$  term of Equation 18 is to dampen numerical oscillations of  $(\partial U_x) / (\partial t)$  by averaging gradients at time  $n$  and  $n+1$ , as shown in Equation 19. This effect may also be effectively accomplished by averaging gradients at times  $n$  and  $n-1$ , which would give

$$U_x \{n+1, i, j, k\} = U_x \{n, i, j, k\} + \left[ \frac{\partial U_x}{\partial t} \{n, i, j, k\} + \frac{\partial U_x}{\partial t} \{n-1, i, j, k\} \right] \frac{\Delta t}{2} \quad (21)$$

Equation 21 was, therefore an efficient method for computing  $U_x\{n+1,i,j,k\}$ . Since  $(\partial U_x)/(\partial t)\{n-1,i,j,k\}$  was already available, less manipulation per time step was required than for other commonly used procedures. Equation 21 provided stability comparable to that of a two-step technique. Both techniques have time step limitations as determined by the Courant-Friedericks-Lewy conditions.

It is conceded that using Equation 21 instead of Equation 19 possibly sacrifices some accuracy in describing unsteady behavior, but if a steady-state solution is the desideratum, then lagging  $(\partial u)/(\partial t)$  by half a time step is inconsequential because all partials with respect to time should asymptotically approach zero.

Once new values of  $U_x$  and  $U_y$  have been computed at each grid intersection  $U_z$  may be calculated from a finite-difference representation of equation 11. Spatial marching can be used in the vertical direction, beginning at the bottom, where  $U_z = 0$ .

The free surface height  $h$  at each horizontal grid intersection may then be calculated. The incompressibility of the fluid requires that the net mass of fluid convected into a volume of fixed horizontal dimensions near the surface has to be accompanied by a comparable adjustment to the surface height of the volume. Since  $U_x$ ,  $U_y$  and  $U_z$  at time  $n+1$  have already been computed in the previous sequence, sufficient data are available to calculate  $(\partial h)/(\partial t)\{n+1,i,j\}$ . The new surface height can be computed from:

$$h\{n+1,i,j\} = h\{n,i,j\} + \left[ \frac{\partial h}{\partial t}\{n,i,j\} + \frac{\partial h}{\partial t}\{n+1,i,j\} \right] \frac{\Delta t}{2} \quad (22)$$

The gradient  $(\partial h)/(\partial t)\{n,i,j\}$  will be known from the previous time step. Note that  $h$  is related to the size of the grid cells which contain the surface; therefore, these cells change volume during the course of the calculations.

The size of the surface elements may be accounted for by identifying  $(h - z_{n+1,x-1}) \equiv a$  and then writing the divergence and momentum equations as follows:

$$\frac{U_{xi} - U_{xi-1}}{x_i - x_{i-1}} + \frac{U_{yj} - U_{yj-1}}{y_j - y_{j-1}} + \frac{U_{zh} - U_{zmax-1}}{a} + \frac{\Delta a}{a \Delta t} = 0 \quad (23)$$

$x$  - momentum ( $y$  - momentum is transformed version of this equation)

$$\begin{aligned} & \frac{\langle \rho a \rangle_t}{a} \frac{\Delta U_x}{\Delta t} + \langle \rho U_x \rangle_x \left( \frac{U_{xi} - U_{xi-1}}{x_i - x_{i-1}} \right) + \langle \rho U_y \rangle_y \left( \frac{U_{yj} - U_{yj-1}}{y_j - y_{j-1}} \right) \\ & + \langle \rho U_z \rangle_z \left( \frac{U_{zh} - U_{zmax-1}}{a} \right) = - \frac{(P_{xi+1} - P_{xi-1})}{2 \Delta x} + \left( \frac{\tau_{xx}|_{xi} - \tau_{xx}|_{xi-1}}{x_i - x_{i-1}} \right) \\ & + \left( \frac{\tau_{yx}|_{yj} - \tau_{yx}|_{yj-1}}{y_j - y_{j-1}} \right) + \left( \frac{\tau_{zx}|_h - \tau_{zx}|_{zmax-1}}{a} \right) \end{aligned} \quad (24)$$

z - momentum

$$\begin{aligned} & \frac{\langle \rho a \rangle_t}{a} \frac{\Delta U_z}{\Delta t} + \langle \rho U_z \rangle_z \left( \frac{U_{zh} - U_{zmax-1}}{a} \right) + \frac{\langle \rho U_y \rangle_y (U_z|_{y_j} - U_z|_{y_{j-1}})}{y_j - y_{j-1}} \\ & + \langle \rho U_x \rangle_x \left( \frac{U_z|_{x_i} - U_z|_{x_{i-1}}}{x_i - x_{i-1}} \right) = - \left( \frac{P_h - P_{zmax-1}}{a} \right) - \rho g \end{aligned} \quad (25)$$

where  $\langle \rangle$  means the average of the quantity within the brackets in the direction of the subscript on the last bracket. The stretched coordinate and the salt continuity equation could have been shown also but these add nothing to the discussion at this point. If  $h = z_{max}$ ,  $a = \Delta z$ , these equations are identical to the interior equations. If the surface does not coincide with a  $z$  grid point (as it never would), the  $U_z|_h = 0$ . This is the normal behavior of these equations. For convenience, a certain number of  $z$ -grid points,  $z_{max}$ , are always used, in which case  $a$  might be negative. This feature imposed the condition that " $a$ " never exceeds  $[z_{max} - z_{max-1}]$  in magnitude. This creates no problem; it is merely described so that the logic of the calculation may be understood.

Pressure, the last dependent variable to be calculated in the sequence of each time step, can be computed by a spatial marching procedure similar to that used to calculate  $U_z$ . At the free surface the pressure will be known, and pressure at lower grid rows can be computed from an integrated form of the  $z$ -momentum equation. An initial adjustment must be made to the pressure at the top grid plane to account for the free surface height.

### Boundary Conditions

Boundary conditions for each dependent variable must be enforced after the sequence in which the variable is computed during the time step. Boundary conditions were applied as shown in Figure 6.

A no-slip condition was enforced along the bottom by forcing the velocity at grid points adjacent to the bottom to fit a boundary-layer-type profile. Grid points lying under the bottom were bypassed. The vertical shear component was set equal to zero as a boundary condition. Wind shear at the surface was empirically related to wind velocity. Heat flux to and from the atmosphere, although neglected in this analysis, could have been included as surface boundary conditions.

Reflection principles were used along the bay banks, where it was felt that the coarse horizontal grid spacing was insufficient to enforce a no-slip condition.

Velocities through the tidal inlets were obtained by extrapolation, for a given tide level and cut-point on the salinity distribution. The cut-point is defined as a level below which there is pure salt water. These conditions could be held constant with

# Specified River Flows

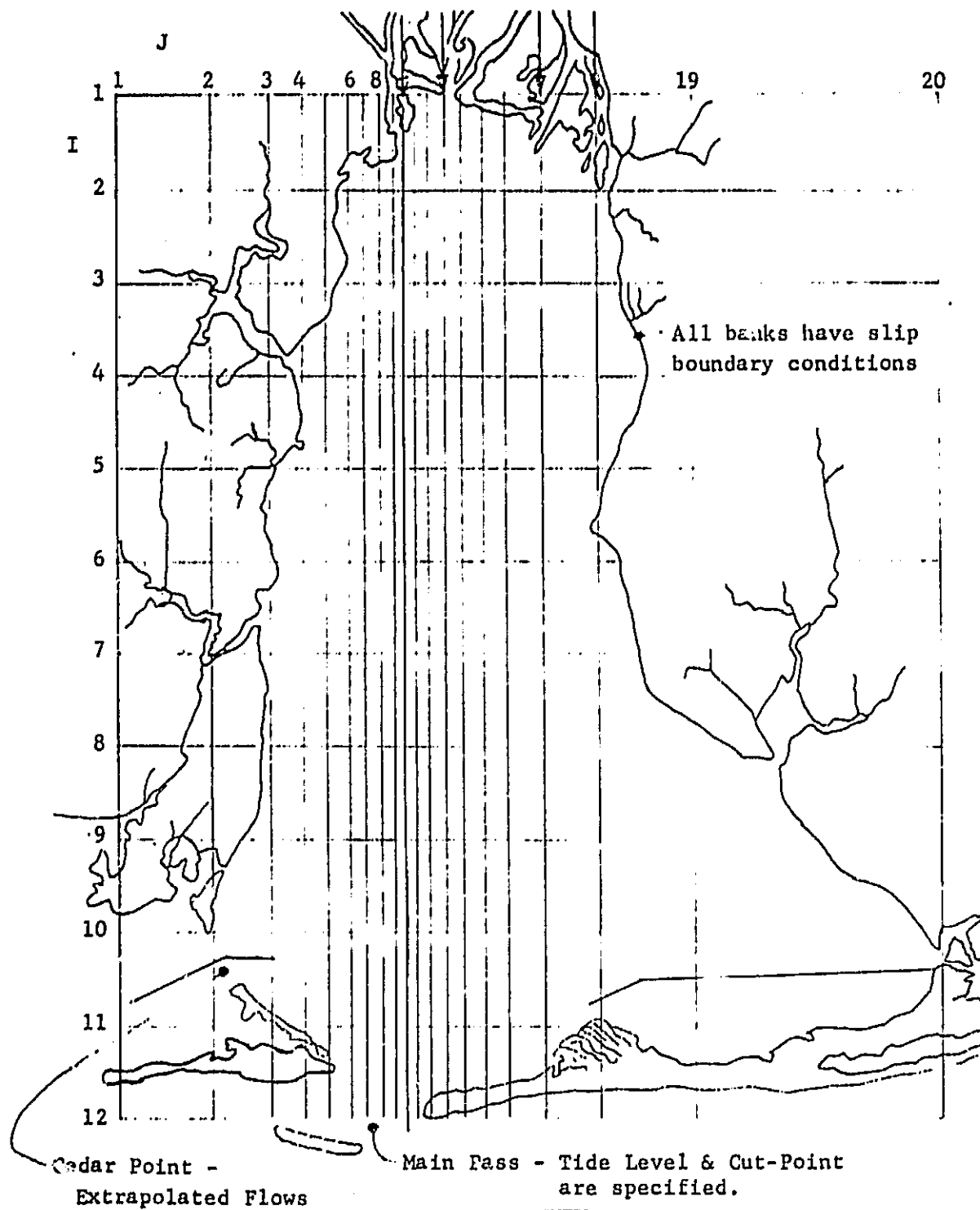


Figure 6a. Boundary Conditions and Grid Locations.

CROSS-SECTIONS PERPENDICULAR  
TO X AXIS

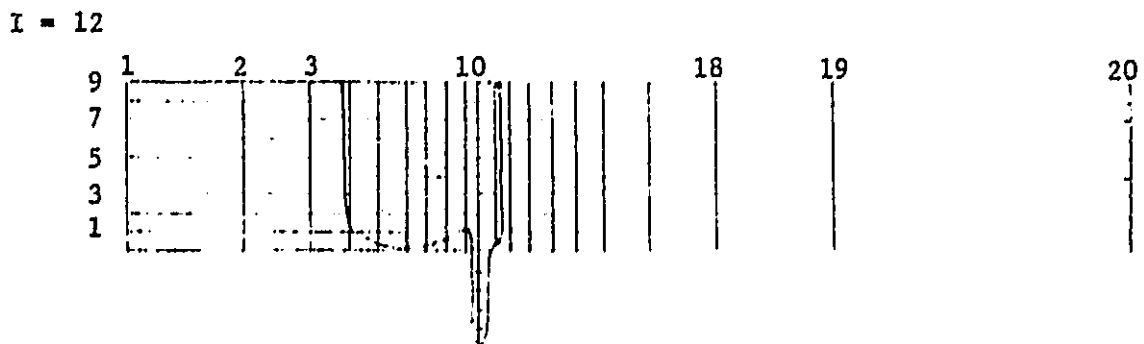
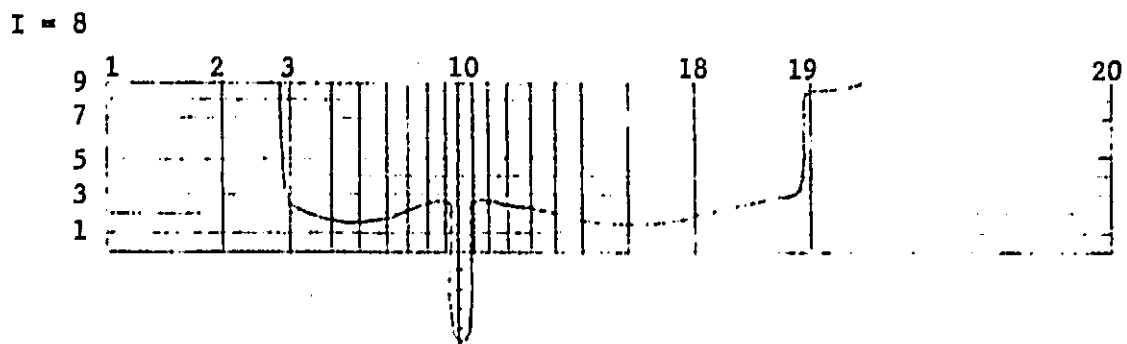
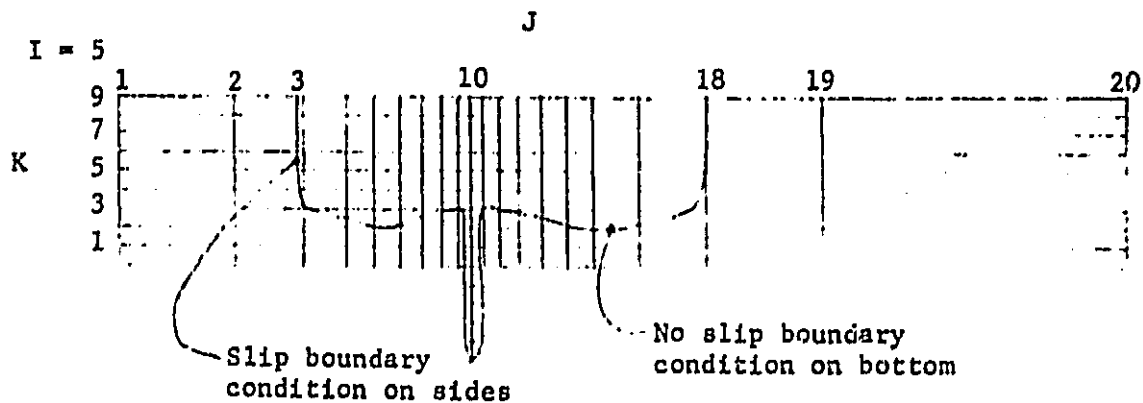


Figure 6b. The Vertical Grid System

time to obtain a steady-state solution, or varied as a known function of time to obtain a time-dependent solution. The tidal effects will be modeled by imposing time varying boundary conditions at the seaward inlets to the harbor. Over part of the tide cycle the river flows will also have to be time dependent. Flows to and from marshes should also be included as part of the specified boundary conditions. These latter two effects have not yet been included in the model.

## RESULTS

The equations presented in the previous chapter constitute the mathematical model of Mobile Bay. The solution technique presented has been implemented with a computer program; this program is listed in the Appendix. Mathematically, the model is a set of partial differential equations which are solved for a particular set of auxiliary conditions. Since the desired solution is a function of time, initial conditions throughout the bay are required; these are not available. In fact, one of the major benefits of using a model is to first predict a quasi-steady or a periodic motion such that an accurate statement of initial conditions is not required. A proposed scheme of generating the necessary initial conditions is presented. The speed and economy of obtaining a solution with this method can now be determined. Initial calculations indicate that more improvement in efficiency is warranted before extensive calculations are made. Several methods of accomplishing this improvement are outlined.

The concept for modeling Mobile Bay is that the three-dimensional, unsteady conservation laws are solved for a set of boundary conditions and an arbitrary set of assumed initial conditions. The boundary conditions are held fixed such that the solution to the equation is driven to an asymptotic limit. This limit then becomes an initial value for a truly unsteady solution. This idea was presented in (8) and applied to modeling a bayou flow problem in (9). The river flows are held fixed. The tide level and a cut-point below which there is only sea water is fixed at the Mobile Point entrance to the bay. Flow through the Cedar Point - Dauphin Island entrance is obtained by extrapolation. These boundary conditions and an initial estimate of all dependent variables are sufficient to begin the sequence of calculations.

The program to perform these calculations is listed as CHANNEL. CHANNEL describes the bay for the stated type of boundary conditions and, in addition, places a specified wind shear on the surface and a no slip condition on the bottom. CHANNEL is a combination of MOBILE 2 and the bayou program from ref. (9). The bayou calculation is included as a description of the ship channel. MOBILE 2\* is also

\*The 2 in its name means it is the second grid configuration which has been used. Generally, there is no difficulty in changing the number of grid points in a calculation, but for this bay calculation some care is necessary, because internal program logic requires that adjacent boundary grids differ by no more than one. This means that the ratios of grid points used should be kept roughly the same.

a three-dimensional, unsteady bay model, but the somewhat more simple bottom location specification allows an overall more simple solution. This development of programs by addition of pre-tested subroutines to a basic main program is by design; this allows one to test and incorporate new features into the calculation without undue program rewriting.

It should be noted that CHANNEL is the culmination of several previous studies which has resulted in significant improvements in this basic analytical approach. Specifically, these improvements are:

- 1) An equation set which has been optimized to run faster by eliminating terms which an order of magnitude analysis showed to be of negligible magnitude.
- 2) A windward differencing scheme was used since it appears to be the fastest explicit scheme yet devised.
- 3) Wind-shear is included as a surface boundary condition.
- 4) The method of applying tidal conditions has been proved to be adequate on the more simple bayou analysis.

Starting with these program features a grid system was developed for Mobile Bay as shown in Fig. 6. Calculations were then initiated to describe the Bay.

A zero mean-sea-level tide condition and a set-point corresponding to field observations at Mobile Point were used as boundary conditions to seek an asymptotic solution. The constancy and smallness of the program generated error functions indicate that suitable progress has been made to begin seeking an unsteady solution. The error functions (SBAR, UBAR, VBAR) are gross measures of the changes in  $S$ ,  $U_x$ ,  $U_y$  between computation steps.

Study of the calculations and review of some of the development steps necessary to obtain these calculations yield the following results.

Stable calculation time is about 0.5 seconds. Modest changes in the grid system point density and using MOBILE 2 rather than CHANNEL does not appreciably change this step size; however, both of these changes do affect the total amount of time necessary to perform a given number of calculation steps. The significant factor which must be considered is the amount of real time which is modeled in a unit of computation time. For CHANNEL and MOBILE 2, these numbers are, about  $6^{-1}$ , for grid system number 2 ( $12 \times 20 \times 9$ ). (Actually, the nine is an eight in MOBILE 2.) Grid system 1 ( $17 \times 30 \times 15$ ) gives about  $25^{-1}$  as the real time to computing time ratio.

Data at intermediate numbers of calculation steps reveal that velocity and surface elevation fields establish before concentration

fields. As expected for the case run the velocities are small, probably because the major driving force in creating flow is the tidal oscillation which have not yet been calculated.

Initially guessed fields take a long time to change - of the order of hours of real time.

The most significant result is that the program has been developed, is running without apparent errors, and is responding as expected to applied boundary conditions.

An unsteady solution has not yet been sought, mainly because the program has only now been developed and run to obtain these initial conditions. Secondly, several observations can be made on the calculations and available experimental data which have a bearing on the immediate steps which need to be made in researching this problem.

River flows as boundary conditions need to be specified so that they can reverse. This means specifying them as a function of time during a tide cycle. Experimental field data at one river stage condition are available and can be used for such a specification.

The ratio of real time to computer time needs to be improved by some or all of the following means.

- 1) Determining if using a larger number of time steps in the species equation than in the momentum equations improves computational efficiency.

- 2) Running on a faster computer. Some runs on machines available to NASA would expedite this study.

- 3) Transform the time variable to reduce the real time length of a tide cycle. Reductions in cycle from 24 hours to about 4 (the lag time for a tidal fluctuation to travel from the south to the north end of the Bay) should prove feasible.

- 4) Devise an improved computation procedure. Possibilities from the simple expedient of devising a new guessing procedure for initialization to using a new differencing formulation will be considered.

In summary, a mathematical model of Mobile Bay has been developed. This model is now ready to use for parametric studies to predict the bay's dynamic behavior. Economy dictates that the exact procedure for accomplishing the required computation be carefully planned and executed.



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## APPENDIX

Discussion of the Program: This appendix describes a computer program which can be used for modeling a bay or estuary with a shipping channel. The mathematical model used in this program is a three-dimensional, time-dependent flow field model which can be used to describe the type flow found in any bay or estuary by changing appropriate boundary conditions and geometry.

Mobile Bay was selected as the bay to be modeled. The computational techniques and equations solved are presented in the chapter on model techniques of the main paper. Comment cards are used throughout in the computer program to indicate which operations are being performed. A simplified flow sheet is presented in Figure 1.

Input Guide: All data cards to be used in the program are read by SUBROUTINE PRELIM. Proceeding each READ statement are comment cards which define each term to be read and specify the appropriate units. These data are nondimensionalized before using them for computations. Two basic formats are used for input, I10 and F10.5. The I10 is an integer format consisting of 10 columns right justified; the F10.5 is a floating point format occupying 10 columns with a decimal point punched on the card.

At the completion of the run, data are written on a tape in SUBROUTINE ECRIRE. This provides data for a restart capability or a plot program.

When the restart capability is used, data are read from a tape by SUBROUTINE LIRE. The option of calling this subroutine is controlled by a data card as described in SUBROUTINE PRELIM.

Table 1 provides the details of the card input.

Description of Printout: This section presents a description of the CHANNEL program output.

Initially, the input parameters are printed in order to identify the problem and to verify that correct values were used. Then a complete description of the grid systems in the three coordinate directions are printed. This description includes index numbers and dimensionless and dimensional values for the locations of the grid planes as well as stretching function values where applicable.

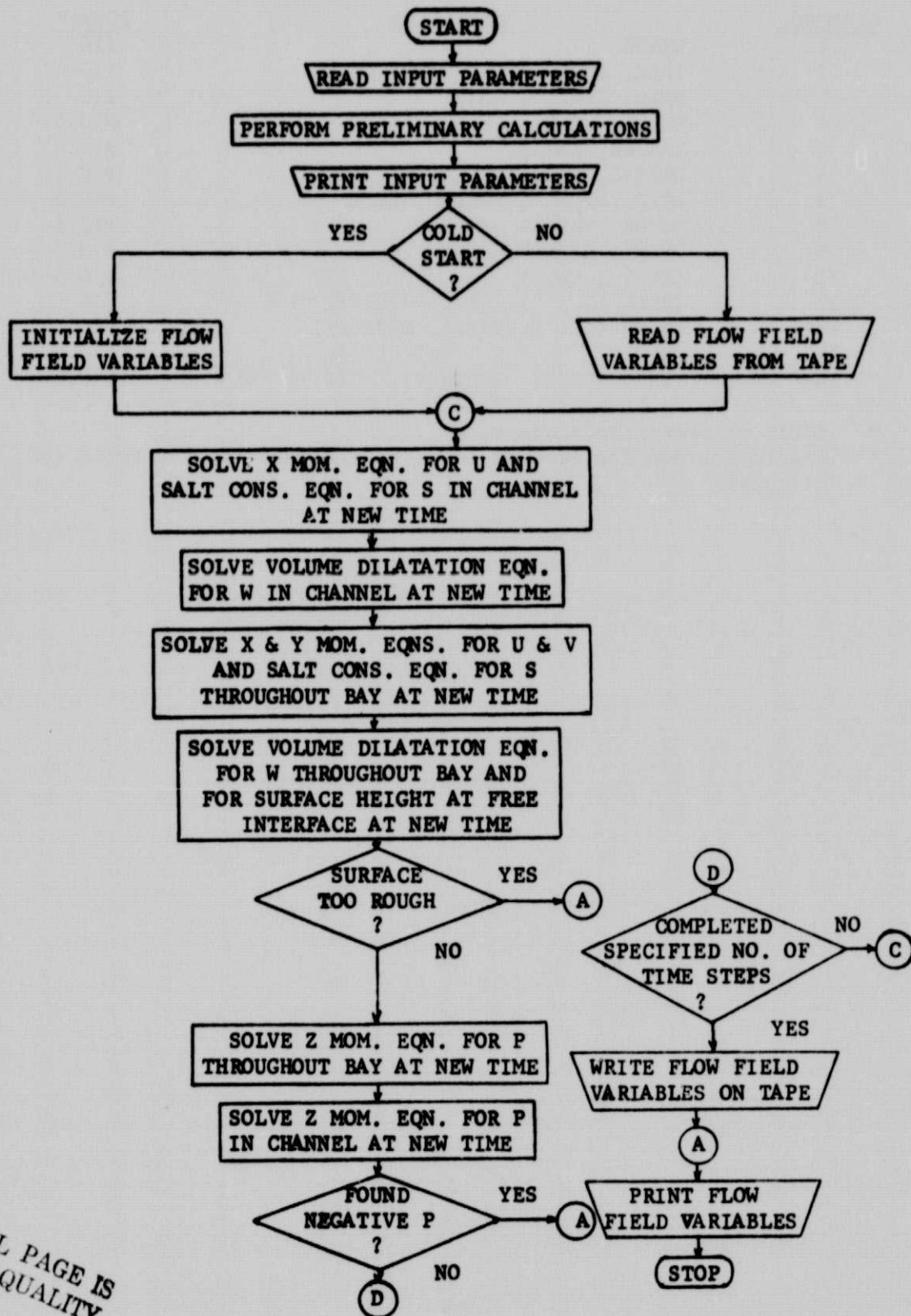
The physical location of the boundaries of the bay are printed as it was read into the program and as the program describes it in terms of the above grid systems. If desired, a description of the floor of the bay can be printed. This portion of the printout is generally suppressed by branching around it with a GØ TØ statement because of its excessive length and low usage. This same comment also applies to a portion of the printout that describes the heights of the banks along the boundaries of the bay. Then the maximum velocities, east and west bank locations and depths of the rivers entering the north end of the bay are printed.

Next, terms monitoring the overall changes in the salinities and horizontal components of velocity for a single time step are printed for selected time steps. If the number of time steps specified in the input data is achieved, a message stating that a stable run was made is given and then values of the flow field variables are printed at selected Y-Z grid planes<sup>1</sup> with velocities in M/S, salinities as fractions of Gulf water salinity and pressures in non-dimensional form. If the surface becomes too rough or a negative pressure below the surface is encountered, a message identifying the cause for premature termination along with its location in the grid system is given. Values of the flow field variables are then printed as above. Finally, the free surface heights relative to the top horizontal grid plane are printed in CM in the form of a map for ease of interpretation.

Program Listing: The following pages contain a listing of CHANNEL and the required input data.

<sup>1</sup>Which Y-Z grid planes are selected is controlled by LOGICAL IF statements that can be modified as needed.

FIGURE 1  
SIMPLIFIED FLOW CHART FOR CHANNEL



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TABLE 1  
INPUT PARAMETERS FOR CHANNEL

<u>CARD NO.</u>	<u>VARIABLES</u>	<u>FORMAT</u>
1	LTAPE	I10
2	IMAX, JMAX, KMAX, JWAG, KMXC	I10
3	NMAX, NPRINT, NBAR	I10
4	FETCH, YMAX	F10.5
5	XBANKN, XBANKS	F10.5
6	DTREAL, YK2, ACCEL	F10.5
7	HREF, SIGMAT, PERIOD, TIDE	F10.5
8	ROUGH, VONKAR	F10.5
9	VWIND, DIRECT, PHI	F10.5
10	CDEPTH, CUTPT	F10.5
11	IIMAX	I10
12*	SOUTH(II), EAST(II), WEST(II)	F10.5
13	CØNVRT	F10.5
14**	YW(I), YE(I), DEPTH(I), URIV(I), RIV	F10.5

\* IIMAX of these cards are read.

\*\* A card is read for each of the 4 rivers entering the north end of the bay.

```

COMMON/DIMEN1/U(2,12,20,11),V(2,12,20,11),W(12,20,11)
COMMON/DIMEN2/S(2,12,20,11),P(12,20,11)
COMMON/DIMEN3/DUDT(12,20,11),DVDT(12,20,11),DHDT(12,20),
1     SURF(12,20)
COMMON/DIMEN4/UC(2,12,11),WC(12,11),SC(2,12,11),PC(12,11),
2     DUCOT(12,11)
COMMON/FLOOR/KFLOOR(12,20),ZB(12,20),KFLOORC(12),ZRC(12)
COMMON/PULL/X(12),Y(20),Z(11),SY(20),SYY(20),YK2,ZC(11)
COMMON/LIMITS/IMAX,IMAXM1,JMAX,JMAXM1,KMAX,KMAXM1,JWAG,KMXC,
3     KMXCM1,KCHANL
COMMON/UNITS/VREF,HREF,GRAV,PI,BETA,FETCH,YMAX,OMEGA,CDEPTH
COMMON/GRID/OX,DY,DZ,DT,DT02,DXINV,DYINV,DZINV,SYJ,SY2,SYJP1,SYJMI
COMMON/VELOCITY/UNEW,UOLD,UIP1,UIM1,UJP1,UJM1,UKP1,UKM1,
4     VNEW,VOLD,VIPI,VIMI,VJPI,VJMI,VKPI,VKMI,
5     WNEW,WIPI,WIMI,WJPI,WJMI,WKPI,WKMI
COMMON/STEP/N,MN,MC,NBAR,NPRINT,NMAX,KEYOUT,LTAPE
COMMON/COORD/SOUTH(22),EAST(22),WEST(22),JEAST(22),JWEST(22)
COMMON/MISC/TOPLYR,SBAR,UBAR,VBAR,VISC,DIFFUS,PREFIX,ACCEL
COMMON/WEDGE/ZW(17)
COMMON/CODES/LW,LR,LT
DIMENSION NI(21)
CALL PRELIM
RHO=1.0+BETA
10 N=N+1
MO=3-MO
MN=3-MN
CALL CHANEL
C     STEP FORWARD IN TIME TO CALC. NEW VALUES OF SALINITY AND THE HORIZONTAL
C     COMPONENTS OF VELOCITY.
CALL SETUP
C     ADJUST VERTICAL COMPONENTS OF VELOCITY AND SURFACE HEIGHT FOR
C     COMPATIBILITY WITH THE HORIZONTAL COMPONENTS OF VELOCITY.
CALL VOLDIL
IF(KEYOUT,NE,0)GO TO 100
C     UPDATE THE PRESSURES OVER THE FIELD.
CALL PRESS

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CALL PRES1
IF(KEYOUT.NE.0)GO TO 100
  C  ALL DEPENDENT VARIABLES HAVE NOW BEEN COMPUTED FOR THIS TIME STEP.
  IF(N.NE.NBAR*(N/NBAR))GO TO 20
  WRITE(LW,1000)N,SBAR,UBAR,VBAR
  NBAR=2*NBAR
  C  20 IF(N.NE.NPRINT*(N/NBAR))GO TO 30
  C  AN INTERMEDIATE WRITE STATEMENT COULD GO HERE.
  C  30 IF(N.LT.NMAX)GO TO 10
  C  DATA IS WRITTEN ON TAPE HERE FOR RESTART OR PLOTTING.
  CALL ECR1RE
  WRITE(LW,1003)
  100 WRITE(LW,1000)N,SBAR,UBAR,VBAR
  WRITE(LW,1001)
  DO 110 I = 1,IMAX
  JW=JWEST(I)
  JE=JEAST(I)
  DO 110 J=JW,JE
  KBOT=KFLOOR(I,J)
  WRITE(LW,1004)
  DO 110 K=KBOT,KMAX
  SNEW=S(MN,I,J,K)
  PNEW=P(I,J,K)
  UNEW=U(MN,I,J,K)*VREF
  VNEW=V(MN,I,J,K)*VREF
  WNEW=W(I,J,K)*VREF
  C  VELOCITIES ARE PRESENTED IN METERS/SEC.
  WRITE(LW,1002)UNEW,VNEW,WNEW,SNEW,PNEW,I,J,K
  110 CONTINUE
  DO 106 I=1,IMAX
  DO 106 J=1,JMAX
  SURF(I,J)=(SURF(I,J)-DZ)*HREF*100.0
  106 CONTINUE
  WRITE(6,1500)
  DO 16 I=1,IMAX
  16 NI(I)=I

```

```

WRITE(6,1501)(NI(I),I=1,IMAX)
DO 17 JJ = 1,JMAX
  J = JMAX+1-JJ
  17 WRITE(6,1502)J,(SURF(I,J),I=1,IMAX)
    WRITE(LW,1011)
    DO 210 K=1,KMXC
      WRITE(LW,1015)
      DO 230 I=1,IMAX
        IF(ZC(K).GT.ZB(I,JWAG))GO TO 210
        U1=UC(MN,I,K)*VREF
        W1=WC(I,K)*VREF
        WRITE(LW,1012)I,K,U1,W1,SC(MN,I,K),PC(I,K)
      230 CONTINUE
    210 CONTINUE
    CALL SWEDGE
    WRITE(LW,1013)
    DO 220 I=1,IMAX
      ZB1=ZBC(I)*HREF
      XTRUE=X(I)*HREF
      ZW1=ZW(I)*HREF
      WRITE(LW,1014)I,ZB1,XTRUE,KFLORC(I),ZW1
    220 CONTINUE
  1000 FORMAT(5X,2HN=14,5X,5HSBAR=1PE13.6,5X,5HUBAR=1PE13.6,5X,5HVBAR=1PE
    & 13.6)
  1001 FORMAT(/,13X,1HU,19X,1HV,19X,1HW,15X,1OHSALT CONC.,11X,8HPRESSURE
    & ,8X,1HI,5X,1HJ,5X,1HK,/)
  1002 FORMAT(5(7X,1PE13.6),3(3X,13))
  1003 FORMAT(/,2X,20HY,ALL DID JUST FINE ,
    & /,2X, YOU HAD A STABLE RUN AND YOU WROTE ON THE TAPE.,
    & /,2X,33HY,ALL COME SEE US AGAIN. BYE NOW.,/)
  1004 FORMAT(/)
  1011 FORMAT(/,22X,'I',7X,'K',8X,'UC',13X,'WC',13X,'SC',13X,'PC',/)
  1012 FORMAT(15X,2(5X,13),4(5X,E12.5))
  1013 FORMAT(/,22X,'I',9X,'ZB-M',10X,'X-M',9X,'KFLORC',5X,
    & 'Z-WEDGE-METERS',/)
  1014 FORMAT(20X,13,9X,F11.5,9X,F9.1,5X,13,7X,F11.5)

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```
1015 FORMAT(/)
1500 FORMAT(///.55X.22HSURFACE HEIGHTS IN CM.,//)
1501 FORMAT(4X,2HI=.21I6,//)
1502 FORMAT(' J=',I2,3X,F5.2,20(1X,F5.2))
      STOP
      END
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ORIGINAL PAGE IS  
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SUBROUTINE PRELIM
COMMON/DIMEN1/U(2,12,20,11),V(2,12,20,11),W(12,20,11)
COMMON/DIMEN2/S(2,12,20,11),P(12,20,11)
COMMON/DIMEN4/UC(2,12,11),WC(12,11),SC(2,12,11),PC(12,11),
      DUCDT(12,11)
COMMON/FLOOR/FLOOR(12,20),ZB(12,20),KFLTRC(12),ZBC(12)
COMMON/PULL/X(12),Y(20),Z(11),SY(20),SZ(20),YK2,ZC(11)
COMMON/LIMITS/IMAX,IMAXM1,JMAX,JMAXM1,KMAX,KMAXM1,JWAG,KMXC,
      KMXCM1,KCHANL
COMMON/UNITS/VREF,HREF,GRAV,PI,BETA,FETCH,YMAX,OMEGA,CDEPTH
COMMON/GRID/DX,DY,DZ,DT,DTO2,DXINV,DYINV,DZINV,SYJ,SYJ2,SYJPI,SYJMI
COMMON/LN/FUNLN1,FUNKAP
COMMON/STEP/N,MN,MO,NBAR,NPRINT,NMAX,KEYOUT,LTAPE
COMMON/FORCES/FWINDX,FWINDY,F
COMMON/TURB/COEFVH,COEFVZ,COEFDH,COEFDZ,RICH,CRICH
COMMON/RIVERS/YW(4),YE(4),DEPTH(4),URIV(4),RMOMAF(4),JRIV(4)
COMMON/COORD/SOUTH(22),EAST(22),WEST(22),JEAST(22),JWEST(22)
COMMON/MISC/TOPLYR,SBAR,UBAR,VBAR,VISC,DIFFUS,PREFIX,ACCEL
COMMON/CODES/LW,LR,LT
COMMON/INDEX/I,J,K
COMMON/PASS/XBANKN,XBANKS,CUTPT,KCUT
      C IF A COLD START IS DESIRED, SET LTAPE = 0
      C IF YOU WANT TO READ FROM THE TAPE, SET LTAPE=1
      READ(LR,1000) LTAPE
      C IMAX,JMAX,KMAX ARE THE MAXIMUM NUMBER OF GRID POINTS IN THE X,Y,Z
      C DIRECTIONS RESPECTIVELY.
      C JWAG IS THE NUMBER OF THE GRID POINT ALONG THE CENTERLINE OF THE SHIP
      C CHANNEL OF THE BAY.
      C KMXC IS THE MAXIMUM NUMBER OF VERTICAL GRID POINTS IN 2-D MODEL
      C OF SHIPPING CHANNEL.
      READ(LR,1000)IMAX,JMAX,KMAX,JWAG,KMXC
      C NMAX IS THE MAXIMUM NUMBER OF TIME STEPS.
      C NPRINT IS THE NUMBER OF A TIME STEP FOR WHICH AN INTERMEDIATE WRITE
      C STATEMENT CAN BE USED, VALUES ARE WRITTEN ON TAPE HERE ALSO.
      C NBAR IS THE TIME STEP NUMBER WHERE SBAR,UBAR,VBAR ARE PRINTED.
      C LET NBAR=1

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READ(LR,1000)NMAX,NPRINT,NBAR
  FETCH IS THE LENGTH OF THE BAY FROM NORTH TO SOUTH IN KILOMETERS
  YMAX IS THE MAX. DISTANCE FROM THE CENTER OF THE SHIP CHANNEL(J=JWAG)
  TO THE EAST BANK.
  YMAX SHOULD BE SLIGHTLY GREATER THAN THE DISTANCE
  FROM THE SHIP CHANNEL TO THE EAST BANK OF THE BAY IN KILOMETERS
  READ(LR,1001) FETCH,YMAX
  XBANKN AND XBANKS ARE LOCATIONS OF THE NORTH AND SOUTH BANKS OF
  A PASS OPENING TO A LARGE BAY TO THE WEST OF THE BAY BEING
  ANALYZED ----- IN KILOMETERS
  READ(LR,1001) XBANKN,XBANKS
  DTREAL IS THE SIZE OF THE TIME STEP IN SECONDS.
  ACCEL IS AN ACCELERATION FACTOR EXPEDITING CONVERGENCE OF THE SALT
  CONSERVATION EQUATION.
  YK1 & YK2 ARE STRETCHING CONSTANTS IN THE EAST-WEST DIRECTION.
  SEE SUBROUTINE RUBER FOR DEFINITIONS, & ADJUST AS REQUIRED, BUT ALWAYS
  MAKE YK2 LESS THAN PI/2.0. YK1 IS CALC. IN SUBROUTINE RUBER
  READ(LR,1001) DTREAL,YK2,ACCEL
  HREF IS THE DEPTH IN METERS WHICH IS SLIGHTLY DEEPER THAN THE DEEPEST
  POINT IN THE BAY EXCLUSIVE OF THE SHIP CHANNEL. THIS DEPTH CORRESPONDS
  TO K=0
  SIGMAT SPECIFIES DENSITY OF SEA WATER RELATIVE TO FRESH WATER
  DENSITY OF FRESH WATER = 1.0 GM PER CUBIC CM.
  SIGMAT = (DENSITY OF SEA WATER - 1.0) * 1000.0
  PERIOD IS THE TIME REQUIRED FOR A COMPLETE TIDAL CYCLE IN HOURS
  TIDE IS HEIGHT DIFFERENCE IN CM. BETWEEN HIGH AND LOW TIDE
  READ(LR,1001) HREF,SIGMAT,PERIOD,TIDE
  ROUGH IS THE DIAMETER OF THE AVERAGE PARTICLE WHICH GENERATES THE
  TURBULENCE ON THE BOTTOM, ROUGH IS MEASURED IN MILLIMETERS.
  VONKAR IS THE VON KARMAN UNIVERSAL BOUNDARY LAYER CONSTANT.
  READ(LR,1001) ROUGH,VONKAR
  VWIND IS THE WIND SPEED IN CM/SEC MEASURED 10 METERS ABOVE THE SURFACE
  DIRECT IS THE DIRECTION WHICH THE WIND IS BLOWING MEASURED IN DEGREES
  AND COUNTERCLOCKWISE FROM THE POSITIVE XAXIS
  PHI IS THE AVERAGE LATITUDE OF THE BAY.
  READ(LR,1001) VWIND,DIRECT,PHI

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C      CDEPTH IS THE DEPTH OF THE SHIPPING CHANNEL BELOW MEAN SEA
C      LEVEL IN METERS.
C      CUTPT IS HEIGHT OF THE SALT WEDGE IN BAY ABOVE K=0 IN METERS.
      READ(LR,1001)CDEPTH,CUTPT
      WRITE(LW,1002)LTAPE,DTREAL,ACCEL
      WRITE(LW,1003)SIGMAT,ROUGH,VONKAR
      WRITE(LW,1004)IMAX,JMAX,KMAX,JWAG,KMXC,NMAX,NPRINT,NBAR
      WRITE(LW,1006)HREF,PERIOD,TIDE
      WRITE(LW,1007)FETCH,YMAX,YK2
      WRITE(LW,1008)VWIND,DIRECT,PHI
      WRITE(LW,1018)CDEPTH,CUTPT
      WRITE(LW,1017) XBANKN,XBANKS
C      READ IIMAX DATA CARDS TO SPECIFY.....
C      1. THE DISTANCE SOUTH OF THE NORTHERN BOUNDARY OF THE BAY.(BEGIN
C      WITH 0.0 & END WITH FETCH)
C      2. THE DISTANCE FROM THE SHIP CHANNEL TO THE EASTERN BOUNDARY OF
C      THE BAY.
C      3. THE DISTANCE FROM THE SHIP CHANNEL TO THE WESTERN BOUNDARY OF THE
C      BAY(NOTE..,ALWAYS NEGATIVE)
C      READ I DATA CARD TO SPECIFY THE CONVERSION FACTOR OF THE UNITS ABOVE
C      TO METERS.
      READ(LR,1000) IIMAX
      XBANKN=(1000.0*XBANKN)/HREF
      XBANKS=(1000.0*XBANKS)/HREF
      DO 2 II=1,IIMAX
2      READ(LR,1001) SOUTH(II),EAST(II),WEST(II)
      READ(LR,1001) CONVRT
      IMAXMI=IMAX-1
      JMAXMI=JMAX-1
      KMAXMI=KMAX-1
      KMXCM1=KMXC-1
      CALL RUBER
      CUTPT=CUTPT/HREF
      K=0
1      K=K+1
      IF(Z(K).LE.CUTPT) GO TO 1

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```

KCUT=K-1
VREF=SQRT(GRAV*HREF)
WRITE(LW,1010)
DO 4 II=1,IMAX
  SOUTH(II)=SOUTH(II)*CONVRT/HREF
  EAST(II)=EAST(II)*CONVRT/HREF
  WEST(II)=WEST(II)*CONVRT/HREF
  SOUTH1=SOUTH(II)*HREF
  EAST1=EAST(II)*HREF
  WEST1=WEST(II)*HREF
4 WRITE(LW,1011) II,SOUTH1,EAST1,WEST1
  I=1
  J=JWAG
6 J=J+1
  IF(Y(J).LT.EAST(1)) GO TO 6
  JEAST(1)=J-1
  J=JWAG
8 J=J-1
  IF(Y(J).GT.WEST(1)) GO TO 8
  JWEST(1)=J+1
  YW1=WEST(1)*HREF
  YE1=EAST(1)*HREF
  YEAST=EAST(1)
  YWEST=WEST(1)
  CALL BOTTOM (YEAST,YWEST)
  WRITE(LW,1013) I,YW1,YE1,JWEST(1),JEAST(1)
  DO 16 I=2,IMAX
    II=1
    10 II=II+1
      IF(SOUTH(II).LT.X(I)) GO TO 10
      WATE=(X(I)-SOUTH(II-1))/(SOUTH(II)-SOUTH(II-1))
      YEAST=EAST(II)*WATE+EAST(II-1)*(1.0-WATE)
      YWEST=WEST(II)*WATE+WEST(II-1)*(1.0-WATE)
      J=JWAG
    12 J=J+1

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```

IF(Y(J).LT.YEAST) GO TO 12
JEAST(I)=J-1
J=JWAG
14 J=J-1
IF(Y(J).GT.YWEST) GO TO 14
JWEST(I)=J+1
YE1=YEAST*HREF
YW1=YWEST*HREF
CALL BOTTOM (YEAST,YWEST)
WRITE(LW,1013) I,YW1,YE1,JWEST(I),JEAST(I)
16 CONTINUE
GO TO 9000
WRITE(LW,1015)
DO 20 I=1,IMAX
J1=JWEST(I)
J2=JEAST(I)
DO 20 J=J1,J2
XREAL=X(I)*HREF
YREAL=Y(J)*HREF
ZBREAL=ZB(I,J)*HREF
20 WRITE(LW,1016) I,J,KFLOOR(I,J),ZB(I,J),XREAL,YREAL,ZBREAL
9000 CONTINUE
C      WANT TO READ THE COORDINATES OF THE WEST & EAST BANKS AND THE DEPTHS
C      OF THE RIVERS FLOWING INTO THE NORTH END OF THE BAY. USE THE SAME UNITS
C      FOR THE EAST AND WEST COORD. AS FOR THE SHORE WITH THE SHIP CHANNEL
C      AS Y=0.0, AND INPUT THE DEPTH IN METERS.
C      AS Y=0.0, AND INPUT THE DEPTH IN METERS.URIV(I) ARE THE MAXI-
C      MUM RIVER VELOCITIES IN METERS/SEC.
COEFDH=0.0025
COEFDZ=0.0025
COEFVH=0.005
COEFVZ=0.005
DO 30 I=1,4
READ(LR,1001) YW(I),YE(I),DEPTH(I),URIV(I),RIV
30 JRIV(I)=IFIX(RIV+0.5)
DO 22 I=1,4

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YW(I)=YW(I)*CONVRT
YE(I)=YE(I)*CONVRT
WRITE(LW,1014)I,YW(I),YE(I),DEPTH(I)
22 WRITE(LW,1005)I,URIV(I)
DO 24 I=1,4
  YW(I)=YW(I)/HREF
  YE(I)=YE(I)/HREF
  DEPTH(I)=DEPTH(I)/HREF
24 URIV(I)=URIV(I)/VREF
  BETA=0.001*SIGMAT
  CRICH=-2.0*BETA*DZ
  F=2.0*OMEGA*SIN(PHI)*HREF/VREF
  ROUGH=0.001*ROUGH/HREF
  FUNLN1=ALOG(0.2/ROUGH)
  FUNKAP=VONKAR*8.5
  FWIND=1.64E-4*(VWIND**1.333)
  FWINDX=FWIND*COS(DIRECT*PI/180.0)
  FWINDY=FWIND*SIN(DIRECT*PI/180.0)
  WRITE(LW,1009) FWIND,FWINDX,FWINDY
  FWINDY=FWINDY/((100.0*VREF)**2)
  FWINDX=FWINDX/((100.0*VREF)**2)
  DT=DTREAL*VREF/HREF
  DT02=0.5*DT
  IF(LTAPE.EQ.0) CALL INITAL
  IF(LTAPE.EQ.1) CALL LIRE
  CALL PRESS
  CALL PRESSC
  DO 50 I=1,IMAX
    JWM1=JWEST(I)-1
    JEP1=JEAST(I)+1
    DO 44 J=1,JWM1
      KBOT=KFLOOR(I,JWM1)
      DO 44 K=KBOT,KMAX
        44 P(I,J,K)=P(I,JWM1+1,K)
        DO 46 J=JEP1,JMAX
          KBOT=KFLOOR(I,JEP1)

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DO 46 K=KBOT,KMAX
46 P(I,J,K)=P(I,JEP1-1,K)
50 CONTINUE
DO 60 I=1,IMAX
DO 61 K=1,KMXC
UC(MO,I,K) = UC(MN,I,K)
SC(MO,I,K) = SC(MN,I,K)
61 CONTINUE
DO 60 J=1,JMAX
DO 60 K=1,KMAX
U(MO,I,J,K)=U(MN,I,J,K)
V(MO,I,J,K)=V(MN,I,J,K)
S(MO,I,J,K)=S(MN,I,J,K)
60 CONTINUE
1000 FORMAT(8I10)
1001 FORMAT(9F10.5)
1002 FORMAT(/,5X,'LTAPE =',I3,/,5X,'DTREAL =',F9.4,' SECONDS',
& 5X,'ACCEL=',F9.4)
1003 FORMAT(/,5X,'SIGMAT =',F9.4,/,5X,'ROUGH =',F9.4,' MILLIMETERS',/,
& 5X,'VON KARMAN CONSTANT =',F9.4)
1004 FORMAT(/,5X,'IMAX =',I3,/,5X,'JMAX =',I3,/,5X,'KMAX =',I3,/,5X,
& 'JWAG =',I3,/,5X,'KMXC =',I3,/,5X,'NMAX =',I4,/,5X,'NPRINT =',I4,
& /,5X,'NBAR =',I3)
1005 FORMAT(/,5X,'MAXIMUM VELOCITY OF RIVER ',I1,' = ',F9.4,' METERS/SE
1C')
1006 FORMAT(/,5X,'HREF =',F9.4,' METERS',/,5X,'PERIOD =',F9.4,' HOURS',
& /,5X,'TIDE =',F9.4,' CM.')
1007 FORMAT(/,5X,'LENGTH OF BAY FROM NORTH TO SOUTH =',F9.4,' KM.',/,
& 5X,'MAX. DIST. FROM CENTER OF SHIP CHANNEL TO EAST BANK =',F9.4,
& ' KM.',/,5X,'YK2 =',F9.4)
1008 FORMAT(/,5X,'WIND SPEED 10 METERS ABOVE SURFACE =',F9.4,' CM/SEC',
& /,5X,'DIRECTION WHICH WIND IS BLOWING =',F9.4,' DEG. ANTICLOCKWISE
& FROM POSITIVE X-AXIS',/,5X,'AVERAGE LATITUDE OF BAY =',F9.4,
& ' DEGREES')
1009 FORMAT(/,5X,6HF'WIND=1PE10.3,2X,'DYNE/CM SQ',
1 5X,7HF'WINDX=1PE10.3,2X,'DYNE/CM SQ',

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      2      5X,7HF,WINDY=1PE10.3,2X,'DYNE/CMSQ',//)
1010  FORMAT(/,15X,'I',15X,'SOUTH1(M)',15X,'EAST1(M)',15X,'WEST1(M)',/)
1011  FORMAT(13X,I4,13X,1PE13.6,2(10X,1PE13.6))
1012  FORMAT(/15X,'I',15X,'YWEST',15X,'YEAST',15X,'JWEST',15X,'JEAST',/)
1013  FORMAT(13X,I3,10X,1PE13.6,7X,1PE13.6,12X,I4,16X,I4)
1014  FORMAT(/,5X,'YW',I1,' = ',F9.3,5X,'YE',I1,' = ',F9.3,5X,'DEPTH',I1
      1      ', ' = ',F9.3)
1015  FORMAT(/10X,'I',10X,'J',10X,'KFLOOR(I,J)',6X,'ZB(I,J)',15X,
      1      'XREAL',14X,'YREAL',15X,'ZBREAL',/)
1016  FORMAT(8X,I3,8X,I3,10X,I4,10X,1PE13.6,10X,1PE13.6,7X,1PE13.6,
      1      5X,1PE13.6)
1017  FORMAT(/,5X,'XBANKN=',F9.4,5X,'XBANKS=',F9.4)
1018  FORMAT(/,5X,'CDEPTH =',F9.4,/,5X,'CUTPT =',F9.4)
      RETURN
      END

```

SUBROUTINE LIRE

A SUBROUTINE TO READ DATA FROM TAPE WHEN LTAPE IS NOT = 0

```

COMMON/DIMEN1/U(2,12,20,11),V(2,12,20,11),W(12,20,11)
COMMON/DIMEN2/S(2,12,20,11),P(12,20,11)
COMMON/DIMEN3/DUOT(12,20,11),DVDT(12,20,11),DHDT(12,20),
1     SURF(12,20)
COMMON/DIMEN4/UC(2,12,11),WC(12,11),SC(2,12,11),PC(12,11),
2     DUCDT(12,11)
COMMON/FLOOR/KFLOOR(12,20),ZB(12,20),KFLOORC(12),ZBC(12)
COMMON/LIMITS/IMAX,IMAXM1,JMAX,JMAXM1,KMAX,KMAXM1,JWAG,KMXC,
3     KMXCM1,KCHANL
COMMON/COORD/SOUTH(22),EAST(22),WEST(22),JEAST(22),JWEST(22)
COMMON/PULL/X(12),Y(20),Z(11),SY(20),SY(20),YK2,ZC(11)
COMMON/STEP/N,MN,MO,NBAR,NPRINT,NMAX,KEYOUT,LTAPE
COMMON/RIVERS/YW(4),YE(4),DEPTH(4),URIV(4),RMOMAF(4),JRIV(4)
COMMON/SHORE/ZBANKN(31),ZBANKS(31),ZBANKE(31),ZBANKW(31)
REWIND 3
READ(3) IMAX,JMAX,KMAX,KMXC,JWAG,
4     (URIV(I),RMOMAF(I),JRIV(I),I=1,4)
READ(3) (ZBANKN(J),J=1,JMAX)
READ(3) (ZBANKS(J),J=1,JMAX)
READ(3) (ZBANKE(J),J=1,JMAX)
READ(3) (ZBANKW(J),J=1,JMAX)
READ(3) (DHDT(I,J),I=1,IMAX),J=1,JMAX)
READ(3) ((DUOT(I,J,K),I=1,IMAX),J=1,JMAX),K=1,KMAX)
READ(3) ((DVDT(I,J,K),I=1,IMAX),J=1,JMAX),K=1,KMAX)
READ(3) ((U(MN,I,J,K),I=1,IMAX),J=1,JMAX),K=1,KMAX)
READ(3) ((V(MN,I,J,K),I=1,IMAX),J=1,JMAX),K=1,KMAX)
READ(3) ((W(I,J,K),I=1,IMAX),J=1,JMAX),K=1,KMAX)
READ(3) ((S(MN,I,J,K),I=1,IMAX),J=1,JMAX),K=1,KMAX)
READ(3) ((P(I,J,K),I=1,IMAX),J=1,JMAX),K=1,KMAX)
READ(3) ((SURF(I,J),I=1,IMAX),J=1,JMAX)
READ(3) ((ZB(I,J),I=1,IMAX),J=1,JMAX)
READ(3) ((KFLOOR(I,J),I=1,IMAX),J=1,JMAX)

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```

READ(3) ((UC(MN,I,K), I=1,IMAX),K=1,KMXC)
READ(3) ((WC(I,K), I=1,IMAX),K=1,KMXC)
READ(3) ((SC(MN,I,K), I=1,IMAX),K=1,KMXC)
READ(3) ((PC(I,K), I=1,IMAX),K=1,KMXC)
READ(3) ((DUCDT(I,K), I=1,IMAX),K=1,KMXC)
READ(3) (ZBC(I), I=1,IMAX)
READ(3) (KFLOOR(I), I=1,IMAX)
RETURN
ENTRY ECRIRE

      AN ENTRY TO WRITE UPDATED DATA ON THE TAPE

REWIND 3
WRITE(3) IMAX,JMAX,KMAX,KMXC,JWAG,
          (URIV(I),RMOMAF(I),JRIV(I),I=1,4)
WRITE(3) (ZBANKN(J),J=1,JMAX)
WRITE(3) (ZBANKS(J),J=1,JMAX)
WRITE(3) (ZBANKE(J),J=1,JMAX)
WRITE(3) (ZBANKW(J),J=1,JMAX)
WRITE(3) ((DHD(I,J),I=1,IMAX),J=1,JMAX)
WRITE(3) ((DUDT(I,J,K),I=1,IMAX),J=1,JMAX),K=1,KMAX)
WRITE(3) ((IDVDT(I,J,K),I=1,IMAX),J=1,JMAX),K=1,KMAX)
WRITE(3) ((U(MN,I,J,K), I=1,IMAX), J=1,JMAX), K=1,KMAX)
WRITE(3) ((V(MN,I,J,K), I=1,IMAX), J=1,JMAX), K=1,KMAX)
WRITE(3) ((W(I,J,K),I=1,IMAX),J=1,JMAX),K=1,KMAX)
WRITE(3) ((S(MN,I,J,K), I=1,IMAX), J=1,JMAX), K=1,KMAX)
WRITE(3) ((P(I,J,K),I=1,IMAX),J=1,JMAX),K=1,KMAX)
WRITE(3) ((SURF(I,J), I=1,IMAX), J=1,JMAX)
WRITE(3) ((ZB(I,J), I=1,IMAX), J=1,JMAX)
WRITE(3) ((KFLOOR(I,J), I=1,IMAX), J=1,JMAX)
WRITE(3) ((UC(MN,I,K), I=1,IMAX),K=1,KMXC)
WRITE(3) ((WC(I,K), I=1,IMAX),K=1,KMXC)
WRITE(3) ((SC(MN,I,K), I=1,IMAX),K=1,KMXC)
WRITE(3) ((PC(I,K), I=1,IMAX),K=1,KMXC)
WRITE(3) ((DUCDT(I,K), I=1,IMAX),K=1,KMXC)
WRITE(3) (ZBC(I), I=1,IMAX)

```

C  
C  
C

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WRITE(3) (KFLORC(I), I=1,IMAX)
WRITE(3) (X(I), I=1,IMAX)
WRITE(3) (Y(J), J=1,JMAX)
WRITE(3) (Z(K), K=1,KMAX)
WRITE(3) (ZC(K), K=1,KMXC)
WRITE(3) (SOUTH(I), I=1,22)
WRITE(3) (WEST(I), I=1,22)
WRITE(3) (EAST(I), I=1,22)
WRITE(3) (JWEST(I), I=1,IMAX)
WRITE(3) (JEAST(I), I=1,IMAX)
RETURN
END

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OF POOR QUALITY

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SUBROUTINE RUBER
COMMON/PULL/X(12),Y(20),Z(11),SY(20),SYY(20),YK2,ZC(11)
COMMON/LIMITS/IMAX,IMAXM1,JMAX,JMAXM1,KMAX,KMAXM1,JWAG,KMXC,
      & KMXCM1,KCHANL
COMMON/GRID/DX,DY,DZ,DT,DT02,DXINV,DYINV,DZINV,SYJ,SY2,SYJPI,SYJMI
COMMON/UNITS/VREF,HREF,GRAV,PI,BETA,FETCH,YMAX,OMEGA,CDEPTH
COMMON/CODES/LW,LR,LT
WRITE(LW,1000)
DX=(FETCH*1000.0/HREF)/FLOAT(IMAXM1)
DXINV=1.0/DX
X1=-DX
DO 10 I=1,IMAX
  X1=X1+DX
  X(I)=X1
  XREAL=X1*HREF
10 WRITE(LW,1001)I,X1,XREAL
  WRITE(LW,1002)
  DY=1.0/FLOAT(JMAX-JWAG)
  DYINV=1.0/DY
  YK1=(YMAX*1000.0)/(HREF*TAN(YK2))
  CONSQ=YK1*YK1
  DO 20 J=1,JMAX
    CAPY=DY*FLOAT(J-JWAG)
    Y1=YK1*TAN(YK2*CAPY)
    Y(J)=Y1
    YREAL=Y1*HREF
    YSQ=Y1*Y1
    DENOM=CONSQ*YSQ
    SY(J)=(1.0/YK2)*YK1/DENOM
    SYY(J)=-((2.0/YK2)*YK1*Y1/(DENOM*DENOM))
20 WRITE(LW,1003)J,Y1,SY(J),SYY(J),YREAL
  WRITE(LW,1004)
  DZ=1.0/FLOAT(KMAX)
  DZINV=1.0/DZ
  Z1=0.0
  DO 30 K=1,KMAX

```

```

Z1=Z1+DZ
Z(K)=Z1
ZREAL=Z1*HREF
30 WRITE(LW,1005)K,Z(K),ZREAL
   WRITE(LW,1006)
   Z1=1.-CDEPTH/HREF
   KCHANL=-FIX(Z1*DZ1NV)+2
   Z1=-FLOAT(KCHANL)*DZ
   DO 40 K=1,KMXC
   Z1=Z1+DZ
   ZC(K)=Z1
   ZREAL=Z1*HREF
   40 WRITE(LW,1005) K,ZC(K),ZREAL
      FORMAT(/,13X,1H1,18X,1HX,15X,8HXREAL(M),/)
      1001 FORMAT(10X,14,11X,1PE13.6,5X,1PE13.6)
      1002 FORMAT(/,13X,1HJ,18X,1HY,15X,2HSY,15X,3HSY,15X,8HYREAL(M),/)
      1003 FORMAT(10X,14,11X,1PE13.6,3(5X,1PE13.6))
      1004 FORMAT(/,13X,1HK,18X,1HZ,15X,8HZREAL(M),/)
      1005 FORMAT(10X,14,11X,1PE13.6,5X,1PE13.6)
      1006 FORMAT(/,13X,1K,17X,1ZC,15X,1REAL(M),/)
      RETURN
   END

```

ORIGINAL PAGE IS  
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```

SUBROUTINE INITIAL
COMMON/DIMEN1/U(2,12,20,11),V(2,12,20,11),W(12,20,11)
COMMON/DIMEN2/S(2,12,20,11),P(12,20,11)
COMMON/DIMEN3/DUDT(12,20,11),DVDT(12,20,11),DHDT(12,20),
1     SURF(12,20)
COMMON/DIMEN4/UC(2,12,11),WC(12,11),SC(2,12,11),PC(12,11),
2     DUCDT(12,11)
COMMON/FLOOR/KFLOOR(12,20),ZB(12,20),KFLORC(12),ZBC(12)
COMMON/PULL/X(12),Y(20),Z(11),SY(20),SYY(20),YK2,ZC(11)
COMMON/LIMITS/IMAX,IMAXM1,JMAX,JMAXM1,KMAX,KMAXM1,JWAG,KMXC,
3     KMXCM1,KCHANL
COMMON/STEP/N,MN,MO,NBAR,NPRINT,NMAX,KEYOUT,LTAPE
COMMON/GRID/DX,DY,DZ,DT,DT02,DXINV,DYINV,DZINV,SYJ,SY2,SYJPI,SYJMI
COMMON/COORD/SOUTH(22),EAST(22),WEST(22),JEAST(22),JWEST(22)
COMMON/RIVERS/YW(4),YE(4),DEPTH(4),URIV(4),RMOMAF(4),JRIV(4)
COMMON/ShORE/ZBANKN(31),ZBANKS(31),ZBANKE(31),ZBANKW(31)
COMMON/PASS/XBANKN,XBANKS,CUTPT,KCUT
4     WILL PUT A FENCE AROUND THE BAY & WILL LATER CUT HOLES WHERE
      APPROPRIATE
DO 2 I=1,IMAX
  ZBANKW(I)=1.01
2  ZBANKE(I)=1.01
DO 4 J=1,JMAX
  ZBANKN(J)=1.01
4  ZBANKS(J)=1.01
      WANT TO SPECIFY INITIAL CONDITIONS IN EACH OF THE RIVER MOUTHS.
      I=1
DO 14 NN=1,4
  YWW= YW(NN)
  YEE = YE(NN)
  DEPTH = DEPTH(NN)
  URIV = URIV(NN)
  WIDTH=YEE-YWW
  AREA1=WIDTH*DEPTH
  J=JRIV(NN)
  KBOT=KFLOOR(I,J)

```

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```

ZBOT=ZB(I,J)
ZBANKN(J)=ZBOT
JM1=J-1
JP1=J+1
WIDTH2=0.5*(Y(JP1)-Y(JM1))
IF(NN.EQ.1)GO TO 6
AREA2=WIDTH2*(1.0+0.01*DZ-ZBOT)
URIVV=URIVV+AREA1/AREA2
URIV(NN)=URIVV
RMOMAF(NN)=AREA2**2/AREA1
GO TO 8
6 AREA2=WIDTH2*DEPTH
URIVV=URIVV+AREA1/AREA2
URIV(NN)=URIVV
RMOMAF(NN)=AREA2**2/AREA1
ZBOT=ZBC(I)
8 DO 14 K=KBOT,KMAX
  VERT=(Z(K)-ZBOT)/(1.0-ZBOT)
  PROFIL=1.0-(1.0-VERT)**7
  U(MN,I,J,K)=URIVV*PROFIL
  V(MN,I,J,K)=0.0
  W(I,J,K)=0.0
  S(MN,I,J,K)=0.0
14 CONTINUE
DO 20 J=1,JMAX
  SURF(I,J)=1.01*DZ
  K=0
18 K=K+1
  IF(K.GT.KMAX) GO TO 20
  IF(Z(K).GE.ZBANKN(J)) GO TO 20
  U(MN,I,J,K)=0.0
  V(MN,I,J,K)=0.0
  W(I,J,K)=0.0
  S(MN,I,J,K)=0.0
  GO TO 18
20 CONTINUE

```



```

C      WILL NOW SPECIFY INITIAL CONDITIONS IN SHIPPING CHANNEL
      URIVV = URIV(I)
      ZBOT=ZBC(I)
      KBOT=KFLORC(I)
      DO 10 K=KBOT,KMXC
      VERT=(ZC(K)-ZBOT)/(1.0-ZBOT)
      PROFIL=1.0-(1.0-VERT)**7
      UCHANL=URIVV*PROFIL
      UC(MN,1,K)=UCHANL
      WC(1,K)=0.0
      SC(MN,1,K)=0.0
      DUCDT(1,K)=0.0
      DO 10 I=2,IMAX
      UC(MN,I,K)=UCHANL
      WC(I,K)=0.0
      SC(MN,I,K)=X(I)/X(IMAX)
      DUCDT(I,K)=0.0
10  CONTINUE
      DO 11 I=1,IMAX
      KBOTM1 = KFLORC(I) - 1
      DO 11 K=1,KBOTM1
      UC(MN,I,K) = 0.
      WC(I,K) = 0.
      SC(MN,I,K) = 0.
      PC(I,K) = 0.
11  DUCDT(I,K) = 0.
C      WILL NOW SPECIFY INITIAL CONDITIONS AT THE MAIN PASS INTO THE
C      SEA
      I=IMAX
      JW=JWEST(I)
      JE=JEAST(I)
      DO 24 J=JW,JE
      ZBANKS(J)=ZB(I,J)
      IF(J.EQ.JWAG) ZBANKS(J)=1.0E-6
      K=0
22  K=K+1

```

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IF(K.GT.KMAX) GO TO 24
IF(Z(K).LT.ZBANKS(J)) GO TO 22
  U(MN,I,J,K)=0.0
IF(K.GT.KCUT) U(MN,I,J,K)=URIV(I)*0.10
V(MN,I,J,K)=0.0
W(I,J,K)=0.0
S(MN,I,J,K)=1.0
GO TO 22
24 CONTINUE
DO 28 J=1,JMAX
  SURF(I,J)=DZ
  K=0
26 K=K+1
  IF(K.GT.KMAX) GO TO 28
  IF(Z(K).GE.ZBANKS(J)) GO TO 28
  U(MN,I,J,K)=0.0
  V(MN,I,J,K)=0.0
  W(I,J,K)=0.0
  IF(K.GT.KCUT) GO TO 28
  S(MN,I,J,K)=1.0
  GO TO 30
29 CONTINUE
  S(MN,I,J,K)=0.0
30 GO TO 26
28 CONTINUE
  WILL NOW SPECIFY INITIAL CONDITIONS IN THE PASS TO THE BAY ON
  THE WEST
  DO 34 I=2,IMAX
  IF(X(I).LT.XBANKN.OR.X(I).GT.XBANKS) GO TO 34
  JW=JWEST(I)
  ZBANKW(I)=ZB(I,JW)
34 CONTINUE
  WILL NOW SPECIFY INITIAL CONDITIONS IN THE BAY PROPER
  DO 39 J=1,JMAX
  39 DHDT(I,J)=0.0
  DO 40 I=2,IMAX

```

C  
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C

```

SALT = (X(I)/X(IMAX))**2
DO 40 J=1,JMAX
DHDT(I,J)=0.0
SURF(I,J)=DZ
DO 40 K=1,KMAX
DUDT(I,J,K)=0.0
DVDT(I,J,K)=0.0
IF(I.EQ.IMAX) GO TO 40
S(MN,I,J,K) = SALT
42 U(MN,I,J,K) = 0.001
IF(K.GT.KCUT) U(MN,I,J,K)=0.2*URIV(I)
V(MN,I,J,K)=0.0
W(I,J,K)=0.0
40 CONTINUE
GO TO 9000
DO 70 J=1,JMAX
70 WRITE(6,1000)J,ZBANKN(J),ZBANKS(J)
WRITE(6,1001)
DO 80 I=1,IMAX
80 WRITE(6,1000)I,ZBANKW(I),ZBANKE(I)
1000 FORMAT(5X,I3,2(2X,1PE10.3))
1001 FORMAT(/)
9000 CONTINUE
RETURN
END

```

SUBROUTINE BOTTOM (YEAST,YWEST)

THE BOTTOM LOCATION IS COMPUTED

```
COMMON/INDEX/I,J,K
COMMON/COORD/SOUTH(22),EAST(22),WEST(22),JEAST(22),JWEST(22)
COMMON/FLOOR/KFLOOR(12,20),ZB(12,20),KFLOORC(12),ZBC(12)
COMMON/PULL/X(12),Y(20),Z(11),SY(20),SYY(20),YK2,ZC(11)
COMMON/LIMITS/IMAX,IMAXMI,JMAX,JMAXMI,KMAX,KMAXMI,JWAG,KMXC,
& KMXCM1,KCHANL
COMMON/UNITS/VREF,HREF,GRAV,PI,BETA,FETCH,YMAX,OMEGA,CDEPTH
DELTAY=1.0/HREF
DELTAX=2.0/HREF
XPRIME=X(1)/X(IMAX)
XFUN=DELTAX*(1.0-XPRIME**3)
DO 10 J=1,JWAG
YPRIME=Y(J)/YWEST
YFUN=0.5*DELTAY*(1.0+COS(2.0*PI*YPRIME))
ZB(I,J)=XFUN+YFUN+1.0E-6
10 CONTINUE
DO 20 J=JWAG,JMAX
YPRIME=Y(J)/YEAST
YFUN=0.5*DELTAY*(1.0+COS(2.0*PI*YPRIME))
ZB(I,J)=XFUN+YFUN+1.0E-6
20 CONTINUE
DO 40 J=1,JMAX
K=0
30 K=K+1
IF(Z(K).LT.ZB(I,J)) GO TO 30
KFLOOR(I,J)=K
KFLOORC(I)=2
ZBC(I)=1-CDEPTH/HREF
40 CONTINUE
RETURN
END
```

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C
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C
SUBROUTINE SETUP
C
C      VALUES ARE CALLED FROM DIMENSIONAL ARRAYS AND ASSIGNED TO
C      NONDIMENSIONED
C      VARIABLES WHICH WILL BE USED IN CALC. NEW VALUES OF U,V,E S
COMMON/DIMEN1/U(2,12,20,11),V(2,12,20,11),W(12,20,11)
COMMON/DIMEN2/S(2,12,20,11),P(12,20,11)
COMMON/DIMEN3/DUCT(12,20,11),DVDI(12,20,11),DHDT(12,20),
1      SURF(12,20)
COMMON/DIMEN4/UC(2,12,11),WC(12,11),SC(2,12,11),PC(12,11),
2      DUCDT(12,11)
COMMON/FLOOR/KFLOOR(12,20),ZB(12,20),KFLOOR(12),ZBC(12)
COMMON/COORD/SOUTH(22),EAST(22),WEST(22),JEAST(22),JWEST(22)
COMMON/PULL/X(12),Y(20),Z(11),SY(20),SYY(20),YK2,ZC(11)
COMMON/LIMITS/IMAX,IMAXM1,JMAX,JMAXM1,KMAX,KMAXM1,JWAG,KMXC,
3      KMXCM1,KCHANL
COMMON/PASS/XBANKN,XBANKS,CUTPT,KCUT
COMMON/GRID/DX,DY,DZ,DT,DT02,DXINV,DYINV,DZINV,SYJ,SY2,SYJPI,SYJM1
COMMON/STEP/N,MN,MC,NBAR,NPRINT,NMAX,KEYOUT,LTAPE
COMMON/UNITS/VREF,HREF,GRAV,PI,BETA,FETCH,YMAX,OMEGA,CDEPTH
COMMON/CONC/SNEW,SOLD,SIP1,SIM1,SJPI,SJM1,SKPI,SKM1,RHO,RHOINV
COMMON/VELCTY/UNEW,UOLD,UIP1,UIM1,UJPI,UJM1,UKPI,UKM1,
4      VNEW,VOLD,VIPI,VIM1,VJPI,VJM1,VKPI,VKM1,
5      WNEW,WIP1,WIM1,WJPI,WJM1,WKPI,WKM1
COMMON/PRES/PK,PIPI,PIM1,PJPI,PJM1
COMMON/TURB/COEFVH,COEFVZ,COEFDH,COEFDZ,RICH,CRICH
COMMON/ShORE/ZBANKN(31),ZBANKS(31),ZBANKE(31),ZBANKW(31)
COMMON/LN/FUNLN1,FUNKAP
COMMON/INDEX/I,J,K
COMMON/MISC/TOPLYR,SBAR,UBAR,VBAR,VISC,DIFFUS,PREFIX,ACCEL
UBAR=0.0
VBAR=0.0
SBAR=0.0
DO 30 I=2,IMAX
X1=X(I)
JW=JWEST(I)

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JE=JEAST(I)
IP1=I+1
IM1=I-1
JWM1=JW-1
SYJ=SY(JWM1)
SYJP1=SY(JW)
DO 20 J=JW,JE
JP1=J+1
JM1=J-1
SY1=SY(J)
SY2=SY(J)
KBOT=KFLOOR(I,J)
KBOTP1=KBOT+1
K = KBOT
ZB1=ZB(I,J)
TOPL YR=SURF(I,J)-0.5*DZ
SYJM1=SYJ
SYJ=SYJP1
SYJP1=SY(JP1)
PREFIX=SYJ*DYINV
      THIS IS A SERIES APPROXIMATION OF A LN FUNCTION
ALPHA1=5.0*(Z(KBOTP1)-ZB1)-1.0
ALPHA2=ALPHA1*ALPHA1
ALPHA3=ALPHA2*ALPHA1
ALPHA4=ALPHA3*ALPHA1
ALPHA5=ALPHA4*ALPHA1
FUNLN2=ALPHA1-0.5*ALPHA2+0.3333*ALPHA3-0.25*ALPHA4+0.2*ALPHA5
FUNLN=(1.0-DZ/(Z(KBOT)-ZB1+0.5*DZ))*(FUNLN1+FUNLN2+FUNKAP))
SOLD=S(MO,I,J,KBOT)
UOLD=U(MO,I,J,KBOT)
VOLD=V(MO,I,J,KBOT)
WNEW=W(I,J,KBOT)
SKM1=SOLD
SKP1=S(MO,I,J,KBOTP1)
UKP1=U(MO,I,J,KBOTP1)
VKP1=V(MO,I,J,KBOTP1)

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C

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WKPI=W(I,J,KBOTPI)
SJM1=S(MO,I,JM1,KBOT)
SJPI=S(MO,I,JPI,KBOT)
VJM1 = V(MO,I,JM1,KBCT)
VJPI = V(MO,I,JPI,KBOT)
SIM1=S(MO,IM1,J,KBCT)
UIM1=U(MO,IM1,J,KBCT)
IF(I.EQ.IMAX)GO TO 4
SIPI=S(MO,IP1,J,KBCT)
UIPI=U(MO,IP1,J,KBOT)
GO TO 5
4 SIPI=1.0
UIPI=UOLD
5 CONTINUE
IF(J.NE.JWAG)GO TO 6
KCMAX=KBOT+KCHANL-1
SKM1=SC(MO,I,KCMAX)
UKM1=UC(MO,I,KCMAX)
VKM1=0.0
WKM1 = WC(I,KCMAX)*0.1906
KIM1=KFLOOR(IM1,J)
IF(KIM1.LE.KBOT) GO TO 3
KCIM1=KIM1+KCHANL-1
UIM1=UC(MO,IM1,KCIM1)
SIM1=SC(MO,IM1,KCIM1)
PIM1=PC(IM1,KCIM1)
GO TO 2
3 PIM1=P(IM1,J,KBOT)
2 PIPI=P(IP1,J,KBOT)
RICH=0.0
RHOINV = 1.0-BETA*SOLD
CALL UVSNEW
U(MN,I,J,K)=UNEW
UBAR=UBAR+ABS(UNEW-UOLD)
S(MN,I,J,K)=SNEW
SBAR=SBAR+ABS(SNEW-SOLD)

```

GO TO 9

6 CONTINUE

C A NEW VALUE OF S AT THE BOTTOM GRID POINT IS NOW COMPUTED

CALL BOTGRD

S(MN,I,J,KBOT)=SNEW

SBAR=SBAR+ABS(SNEW-SOLD)

9 CONTINUE

DO 10 K=KBOTPI,KMAXMI

KPI=K+1

KMI=K-1

SKMI=SOLD

SOLD=SKPI

SKPI=S(MO,I,J,KPI)

UKMI=UOLD

UOLD=UKPI

UKPI=U(MO,I,J,KPI)

VKMI=VOLD

VOLD=VKPI

VKPI=V(MO,I,J,KPI)

WKMI=WNEW

WNEW=WKPI

WKPI=W(I,J,KPI)

SIMI=S(MO,IM1,J,K)

SJM1=S(MO,I,JM1,K)

SJPI=S(MO,I,JPI,K)

UIM1=U(MO,IM1,J,K)

UJM1=U(MO,I,JM1,K)

UJPI=U(MO,I,JPI,K)

VIM1=V(MO,IM1,J,K)

VJM1=V(MO,I,JM1,K)

VJPI=V(MO,I,JPI,K)

PIM1=P(IM1,J,K)

PJM1=P(I,JM1,K)

PJPI=P(I,JPI,K)

IF(I.EQ.IMAX)GO TO 7

SIP1=S(MO,IP1,J,K)

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UPI=U(MO,IP1,J,K)
VIP=V(MO,IP1,J,K)
PIP=P(IP1,J,K)
GO TO 8
7 SIP=1.0
UPI=UOLD
VIP=VOLD
PIP=1.5*P(I,J,K)-0.5*PIPI
8 CONTINUE
C THE RICHARDSON NO. IS COMPUTED
QKPI=SQRT(UKPI*UKPI+VKPI*VKPI)
QKM1=SQRT(UKM1*UKM1+VKM1*VKM1)
DQ=QKPI-QKM1
RICH=CRICH*(SKPI-SKM1)/(DQ*DQ+1.0E-6)
IF(RICH.LT.0.0)RICH=0.0
RHOINV=1.0-BETA*SOLD
C NEW VALUES OF U,V,& S AT INTERIOR GRID PTS. ARE COMPUTED
CALL UVSNEW
S(MN,I,J,K)=SNEW
SBAR=SBAR+ABS(SNEW-SOLD)
U(MN,I,J,K)=UNEW
UBAR=UBAR+ABS(UNEW-UOLD)
V(MN,I,J,K)=VNEW
VBAR=VBAR+ABS(VNEW-VOLD)
10 CONTINUE
C NEW VALUES OF U & V AT THE BOTTOM GRID PT. IS DETERMINED BY A
C LN CURVE FIT
IF(J.EQ.JWAG)GO TO 13
U(MN,I,J,KBOT)=U(MN,I,J,KBCTPI)*FUNLN
13 CONTINUE
V(MN,I,J,KBOT)=V(MN,I,J,KBCTPI)*FUNLN
K=KMAX
SIM1=S(MO,IM1,J,K)
SJM1=S(MO,I,JM1,K)
SJP1=S(MO,I,JPI,K)
JIM1=U(MO,IM1,J,K)

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ORIGINAL PAGE IS  
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UJM1=U(MO,I,JM1,K)
UJP1=U(MO,I,JPI,K)
VIM1=V(MO,IM1,J,K)
VJM1=V(MO,I,JM1,K)
VJP1=V(MO,I,JPI,K)
PIM1=P(IM1,J,K)
PJM1=P(I,JM1,K)
PJP1=P(I,JPI,K)
SKM1=SOLD
SOLD=SKP1
UKM1=UOLD
UOLD=UKP1
VKM1=VOLD
VOLD=VKP1
WKM1 = WNEW
WNEW = WKP1
WKP1 = 0.0

```

```

RHOINV=1.0-BETA*SOLD

```

VALUES OF U,V,ES ABOVE THE SURFACE ARE THE SAME AS THOSE ON THE SURFACE.

```

IF(I.EQ.IMAX) GO TO 11
PIP1=P(IP1,J,K)
SIP1=S(MO,IP1,J,K)
UIP1=U(MO,IP1,J,K)
VIP1=V(MO,IP1,J,K)
GO TO 12
11 SIP1=1.0
UIP1=UOLD
VIP1=VOLD
PIP1=1.5*P(I,J,K)-0.5*PIM1
12 RICH=0.5*RICH
CALL SURFAC
S(MN,I,J,K)=SNEW
SBAR=SBAR+ABS(SNEW-SOLD)
U(MN,I,J,K)=UNEW
UBAR=UBAR+ABS(UNEW-UOLD)

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```

V(MN,I,J,K)=VNEW
VBAR=VBAR+ABS(VNE*-VCLD)
20 CONTINUE
JWM1=JW-1
JEP1=JE+1
KBOTW=KFLOOR(I,JWM1)
KBOTE=KFLOOR(I,JEP1)
DO 24 K=KBOTW,KMAX
  IF(Z(K).GE.ZBANKW(I)) GO TO 22
  S(MN,I,JWM1,K)=S(MN,I,JW,K)
  IF(X1.LT.XBANKN.OR.X1.GT.XBANKS) GO TO 24
  U(MN,I,JWM1,K)=U(MN,I,JW,K)
  V(MN,I,JWM1,K)=V(MN,I,JW,K)
  S(MN,I,JWM1,K)=S(MN,I,JW,K)
24 CONTINUE
DO 28 K=KBOTE,KMAX
  IF(Z(K).GE.ZBANKE(I)) GO TO 28
  S(MN,I,JEP1,K)=S(MN,I,JE,K)
28 CONTINUE
30 CONTINUE
I=1
JW=JWEST(1)
JE=JEAST(1)
DO 32 J=JW,JE
  KBOT=KFLOOR(1,J)
  DO 32 K=KBOT,KMAX
    IF(Z(K).GE.ZBANKN(J)) GO TO 32
    S(MN,I,J,K)=S(MN,2,J,K)
32 CONTINUE
I=IMAX
JW=JWEST(IMAX)
JE=JEAST(IMAX)
DO 34 J=JW,JE
  KBOT=KFLOOR(IMAX,J)
  DO 34 K=KBOT,KMAX
    IF(Z(K).GE.ZBANKS(J)) GO TO 34

```

```

S(MN,I,J,K)=S(MN,IMAXM1,J,K)
34 CONTINUE
DO 36 I=2,IMAX
  JW=JWEST(I)
  JE=JEAST(I)
  DO 36 J=JW,JE
    KBOT=KFLOOR(I,J)
    IF(KBOT.EQ.1) GO TO 36
    KBTM1=KBOT-1
    S(MN,I,J,KBTM1)=S(MN,I,J,KBOT)
36 CONTINUE
  RETURN
END

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ORIGINAL PAGE IS  
OF POOR QUALITY



```

12 CONTINUE
GO TO 11
13 COMPU1=UOLD*UOLD-UIMI*UIMI*RMOMAF(NN)
GO TO 14
11 COMPU1=UOLD*UOLD-UIMI*UIMI
14 COMPU1=VOLD*VOLD-VIMI*VIMI
COMPS1=0.5*(UOLD+UIMI)*(SOLD-SIMI)
15 COMPU2=0.5*RHQIN*(PIPI-PIMI)
COMPU2=0.5*RHQIN*(PJP1-PJMI)
IF(VOLD.GT.0.0) GO TO 20
SY1=0.5*(SYJ+SYJP1)
COMPU3=UJP1*VJP1-UOLD*VOLD
COMPU3=VJP1*VJP1-VOLD*VOLD
COMPS3=0.5*(VJP1+VOLD)*(SJPI-SOLD)
GO TO 25
20 SY1=0.5*(SYJ+SYJMI)
COMPU3=UOLD*VOLD-UJMI*VJMI
COMPU3=VOLD*VOLD-VJMI*VJMI
COMPS3=0.5*(VOLD+VJMI)*(SOLD-SJMI)
25 IF(WNEW.GT.0.0) GO TO 30
COMPU4=UKP1*WKPI-UOLD*WNEW
COMPU4=VKP1*WKPI-VOLD*WNEW
COMPS4=0.5*(WKPI+WNEW)*(SKPI-SOLD)
GO TO 35
30 COMPU4=UOLD*WNEW-UKM1*WKMI
COMPU4=VOLD*WNEW-VKM1*WKMI
COMPS4=0.5*(WNEW+WKMI)*(SOLD-SKMI)
35 CONTINUE

C
C      NOW SOLVING THE X-MOMENTUM EQUATION.
C      CALL VISCUS
C
C      DU/DT= -(D(U*U)/DX + D(U*V)/DY + D(U*W)/DZ + (1.0/RHQ)*DP/DX)
C              + COEFVX*(DSQU/DXSQ) + COEFVY*(DSQU/DYSQ) + COEFVZ*(DSQU/DZSQ)
C              + FWINDX/(RHO*DEPTH)
C
C

```

```

DUODT=-DXINV*(COMPU1+COMPU2)-SY1*DYINV*COMPU3
& -DZINV*COMPU4+VISC+F*VOLD+WINDX
UNEW=UOLD+(DUODT+DUDT(I,J,K))*DTOT2
DUDT(I,J,K)=DUODT
      NOW SOLVING THE Y-MOMENTUM EQUATION.
      CALL VVISC
C
C      DV/DT= -(D(U*V)/DX + D(V*V)/DY + D(V*W)/DZ + (1.0/RHO)*DP/DY)
C      + COEFVX*(DSQV/DXSQ) + COEFVY*(DSQV/DYSQ) + COEFVZ*(DSQV/DZSQ)
C      + FWINDY/(RHO*DEPTH)
C
C      DVODT=-DXINV*COMPV1-SY1*DYINV*(COMPV2+COMPV3)
C      & -DZINV*COMPV4+VISC-F*UOLD+WINDY
C      VNEW=VOLD+(DVODT+DVDT(I,J,K))*DTOT2
C      DVDT(I,J,K)=DVODT
C      NOW SOLVING THE CONSERVATION OF SALT EQUATION.
C
C      40 CALL DIFUSE
C      DSODT=-DXINV*COMPS1-SY1*DYINV*COMPS3
C      & -DZINV*COMPS4+DIFFUS
C      SNEW=SOLD+DSODT*DT*ACCEL
C      IF(SNEW.LT.0.0)SNEW=0.0
C      IF(I.EQ.IMAX.AND.K.LE.KCUT)SNEW=1.0
C      RETURN
C      THIS IS A SPECIAL ENTRY FOR CALC. S AT THE BOTTOM GRID PT.
C      ENTRY BOTGRD
C      RICH=0.0
C      IF(UOLD.GT.0.0) GO TO 45
C      COMPS1=0.5*(UIP1+UOLD)*(SIP1-SOLD)
C      GO TO 50
C      45 COMPS1=0.5*(UOLD+UIM1)*(SOLD-SIM1)
C      50 IF(VOLD.GT.0.0) GO TO 55
C      SY1=0.5*(SYJ+SYJP1)
C      COMPS3=0.5*(VJP1+VOLD)*(SJP1-SOLD)
C      GO TO 60
C      55 SY1=0.5*(SYJ+SYJM1)
C      COMPS3=0.5*(VOLD+VJM1)*(SOLD-SJM1)

```

```
60 COMPS4=0.0  
GO TO 40  
END
```



```

SUBROUTINE VISCUS
COMMON/GRID/DX,DY,DZ,DT,DT02,DXINV,DYINV,DZINV,SYJ,SY2,SYJPI,SYJMI
COMMON/VELOCITY/UNEW,UOLD,UIPI,UIMI,UJPI,UJMI,UKPI,UKMI,
&      VNEW,VOLD,VIPI,VIMI,VJPI,VJMI,VKPI,VKMI,
&      WNEW,WIPI,WIMI,WJPI,WJMI,WKPI,WKMI
COMMON/CONC/SNEW,SOLD,SIP1,SIMI,SJPI,SJMI,SKM1,SKMI,RHO,RHOINV
COMMON/TURB/COEFVH,COEFVZ,COEFDH,COEFDZ,RICH,CRICH
COMMON/MISC/TOPLYR,SBAR,UBAR,VBAR,VISC,DIFFUS,PREFIX,ACCEL

      EDDY VISCOSITY TERMS ARE CALCULATED.

      THIS SECTION COMPUTES TERMS FOR THE X-MOM. EQ.

      DAMPV=1.0/SQRT(1.0+10.0*RICH)
      TWOU=UOLD+UOLD
      XCOMP=DXINV*DXINV*(UIPI-TWOU+UIMI)
      YCOMP1=SY2*0.5*DYINV*(UJPI-UJMI)
      YCOMP2=PREFIX*PREFIX*(UJPI-TWOU+UJMI)
      ZCOMP=DZINV*DZINV*(UKPI-TWOU+UKMI)
      GO TO 10
      ENTRY VVISC

      THIS SECTION COMPUTES TERMS FOR THE Y-MOM. EQ.

      TWOV=VOLD+VOLD
      XCOMP=DXINV*DXINV*(VIPI-TWOV+VIMI)
      YCOMP1=SY2*0.5*DYINV*(VJPI-VJMI)
      YCOMP2=PREFIX*PREFIX*(VJPI-TWOV+VJMI)
      ZCOMP=DZINV*DZINV*(VKPI-TWOV+VKMI)
10  VISC=COEFVH*(XCOMP+YCOMP1+YCOMP2)+COEFVZ*DAMPV*ZCOMP
      RETURN

      ENTRY DIFUSE

      EDDY DIFFUSION TERMS ARE CALCULATED.

```

```

DAMPD=1.0/(1.0+3.33*RICH)*1.5
TWOS=SOLD+SOLD
XCOMP=DXINV*DXINV*(SIP1-TWOS+SJM1)
YCOMP1=SY2*0.5*DYINV*(SJP1-SJM1)
YCOMP2=PREFIX*PREFIX*(SJP1-TWOS+SJM1)
ZCOMP=DZINV*DZINV*(SKP1-TWOS+SKM1)
DIFFUS=COEFDH*(XCOMP+YCOMP1+YCOMP2)+COEFDZ*DAMPD*ZCOMP
RETURN
END

```

```

SUBROUTINE VOL01L
C
C      NEW VALUES OF W & SURFACE HTS. ARE CALC.
C
COMMON/DIMEN1/U(2,12,20,11),V(2,12,20,11),W(12,20,11)
COMMON/DIMEN3/DUDT(12,20,11),DVDT(12,20,11),DHDT(12,20),
1      SURF(12,20)
COMMON/DIMEN4/UC(2,12,11),WC(12,11),SC(2,12,11),PC(12,11),
&      DUCDT(12,11)
COMMON/FLOOR/KFLOOR(12,20),ZB(12,20),KFLORC(12),ZBC(12)
COMMON/COORD/SOUTH(22),EAST(22),WEST(22),JEAST(22),JWEST(22)
COMMON/LIMITS/IMAX,IMAXM1,JMAX,JMAXM1,KMAX,KMAXM1,JWAG,KMXC,
&      KMXCM1,KCHANL
COMMON/PULL/X(12),Y(20),Z(11),SY(20),SYY(20),YK2,ZC(11)
COMMON/GRID/DX,DY,DZ,DT,DT02,DXINV,DYINV,DZINV,SYJ,SY2,SYJP1,SYJM1
COMMON/STEP/N,MN,MO,NBAR,NPRINT,NMAX,KEYOUT,LTAPE
COMMON/CODES/LW,LR,LT
DIMENSION TEMPRY(20),SAVE(20)
DO 5 J=1,JMAX
5  SAVE(J)=SURF(1,J)
  JWIM1=JWEST(1)
  JEIM1=JEAST(1)
  DO 30 I=2,IMAXM1
    IM1=I-1
    IP1=I+1
    JW=JWEST(1)
    JE=JEAST(1)
    SURF1=SURF(I,JW)
    SURFJP=SURF1
    KCMAX=KFLOOR(I,JWAG)+KCHANL-1
    DO 20 J=JW,JE
      JP1=J+1
      JM1=J-1
      SY1=SY(J)
      Y1=Y(J)
      YJP1=Y(JP1)

```

```

YJM1=Y(JM1)
DELY=0.5*(YJP1-YJM1)
DELYIN=1.0/DELY
DELY1=Y1-YJM1
DELY2=YJP1-Y1
SURFJM=SURF1
SURF1=SURFJP
SURFJP=SURF(I,JP1)
SURFIM=SURF(IM1,J)
SURFIP=SURF(IP1,J)
KBOT=KFLOOR(I,J)
KBOTP1=KBOT+1
K=KBOT
UI=U(MN,I,J,K)
UIM1=U(MN,IM1,J,K)
UIP1=U(MN,IP1,J,K)
VI=V(MN,I,J,K)
VJM1=V(MN,I,JM1,K)
VJP1=V(MN,I,JP1,K)
Z1=Z(K)
ZB1=ZB(I,J)
ZBIM=0.5*(ZB1+ZB(IM1,J))
ZBIP=0.5*(ZB1+ZB(IP1,J))
ZBJM=0.5*(ZB1+ZB(I,JM1))
ZBJP=0.5*(ZB1+ZB(I,JP1))
VIN=0.25*(UI+UIM1)
UOUT=0.25*(UI+UIP1)
VIN=0.25*(VI+VJM1)
VOUT=0.25*(VI+VJP1)
WNEW=DXINV*(UIN*(Z1-ZBIM)-UOUT*(Z1-ZBIP))
6   +DELYIN*(VIN*(Z1-ZBJM)-VOUT*(Z1-ZBJP))
    IF(J.NE.JWAG) GO TO 6
WNEW=WNEW+WC(I,KMAX)*0.1906
6   W(I,J,KBOT) = WNEW
    DO 10 K=KBOTP1,KMAX
    KM1=K-1

```

```

UIMKM1=UIM1
UIM1=U(MN,IM1,J,K)
UIPKM1=UIP1
UIP1=U(MN,IP1,J,K)
VJMKM1=VJM1
VJM1=V(MN,I,JM1,K)
VJPKM1=VJP1
VJP1=V(MN,I,JP1,K)
UIN=0.25*(UIM1+UIMKM1)
UOUT=0.25*(UIP1+UIPKM1)
VIN=0.25*(VJM1+VJMKM1)
VOUT=0.25*(VJP1+VJPKM1)
WIN=0.50*WNEW+0.125*((UIM1,J,KM1)+W(IP1,J,KM1))
E +(W(I,JM1,KM1))*DELY1+W(I,JP1,KM1)*DELY2)*DELYIN)
WNEW=WIN-((UOUT-UIN)*DXINV+(VOUT-VIN)*DELYIN)*DZ
10 W(I,J,K)=WNEW
UKM1=U(MN,I,J,KMAXM1)
UI=U(MN,I,J,KMAX)
VKM1=V(MN,I,J,KMAXM1)
VI=V(MN,I,J,KMAX)
UIN=0.25*(UI+UIM1+UKM1+UIMKM1)
UOUT=0.25*(UI+UIP1+UKM1+UIPKM1)
VIN=0.25*(VI+VJM1+VKM1+VJMKM1)
VOUT=0.25*(VI+VJP1+VKM1+VJPKM1)
SURFV=0.5*SURF1+0.125*((SURFIM+SURFIP)
E +(SURFJM*DELY1+SURFJP*DELY2)*DELYIN)
DHODT=WIN+0.5*((UIN*(SURF1+SURFIM)-UOUT*(SURF1+SURFIP))*DXINV
E +(VIN*(SURF1+SURFJM)-VOUT*(SURF1+SURFJP))*DELYIN)
SURF2=SURFV+(DHODT+DHODT(I,J))*DT02
DHODT(I,J)=DHODT
TEMPRY(J)=SURF2
IF(SURF2.GE.0.5*DZ) GO TO 20
WRITE(LW,1000) N,I,J
KEYOUT=1
RETURN
20 CONTINUE

```

```

DO 21 J=JWIM1,JEIM1
21 SURF(IM1,J)=SAVE(J)
DO 22 J=JW,JE
22 SAVE(J)=TEMPRY(J)
JWIM1=JW
-JEIM1=JE
SURF(IM1,JW-1) = SURF(IM1,JW)
SURF(IM1,JE+1) = SURF(IM1,JE)
30 CONTINUE
DO 39 J = JW,JE
39 SURF(IMAXM1,J) = TEMPRY(J)
SURF(IMAXM1,JW-1) = SURF(IMAXM1,JW)
SURF(IMAXM1,JE+1) = SURF(IMAXM1,JE)
DO 40 J=1,JMAX
SURF(1,J)=SURF(2,J)
KBOT=KFLOOR(1,J)
DO 50 K=KBOT,KMAX
50 W(1,J,K)=W(2,J,K)
KBOT=KFLOOR(IMAX,J)
DO 60 K=KBOT,KMAX
60 W(IMAX,J,K)=W(IMAXM1,J,K)
40 CONTINUE
1000 FORMAT(/,5X,' I AM GOING TO QUIT BECAUSE THE SURF IS TOO ROUGH AT'
      2 ,5X,2HN=14,5X,2HI=13,5X,2HJ=13)
RETURN
END

```

```

SUBROUTINE PRESS
COMMON/DIMEN1/U(2,12,20,11),V(2,12,20,11),W(12,20,11)
COMMON/DIMEN2/S(2,12,20,11),P(12,20,11)
COMMON/DIMEN3/DUDT(12,20,11),DVDI(12,20,11),DHOT(12,20),
      SURF(12,20)
COMMON/DIMEN4/UC(2,12,11),WC(12,11),SC(2,12,11),PC(12,11),
      DUCDT(12,11)
COMMON/FLOOR/KFLOOR(12,20),ZB(12,20),KFLORC(12),ZBC(12)
COMMON/COORD/SOUTH(22),EAST(22),WEST(22),JEAST(22),JWEST(22)
COMMON/PULL/X(12),Y(20),Z(11),SY(20),SYY(20),YK2,ZC(11)
COMMON/LIMITS/IMAX,IMAXM1,JMAX,JMAXM1,KMAX,KMAXM1,JWAG,KMXC,
      KMXCM1,KCHANL
COMMON/UNITS/VREF,HREF,GRAV,PI,BETA,FETCH,YMAX,CMEGA,CDEPTH
COMMON/GRID/DX,DY,DZ,DT,DT02,DXINV,DYINV,DZINV,SYJ,SY2,SYJP1,SYJM1
COMMON/CONC/SNEW,SOLD,SIP1,SIM1,SJP1,SKM1,SKM1,RHO,RHOINV
COMMON/STEP/N,MN,MC,NBAR,NPRINT,NMAX,KEYOUT,LTAPE
COMMON/CODES/LW,LR,LT

```

THIS IS A SUBROUTINE TO CALCULATE PRESSURE

```

DO 40 I=1,IMAX
IM1=I-1
IP1=I+1
JE=JEAST(I)
JW=JWEST(I)
DO 30 J=JW,JE
JM1=J-1
JP1=J+1
K=KMAX
SY1=SY(J)
SK=S(MN,I,J,K)
RHO=1.0+BETA*SK
IF(I.EQ.1.OR.I.EQ.IMAX) GO TO 12
COMPX=(U(MN,IP1,J,K)*W(IP1,J,K)-U(MN,IM1,J,K)*W(IM1,J,K))
      *(0.5*DXINV)
GO TO 14

```

```

12 COMPX=0.0
14 COMPY=(V(MN,I,JPI,K)*W(I,JPI,K)-V(MN,I,JM1,K)*W(I,JM1,K))
   & *(0.5*SYI*DYINV)
   PK=RHO*(1.0+COMPX+COMPY)*(SURF(I,J)-DZ)
   P(I,J,KMAX)=PK
   WK=W(I,J,KMAX)
   KBOT=KFLOOR(I,J)
   KMAX=KMAX-KBOT
   DO 20 KK=1,KMAX
   K=KMAX-KK
   PKPI=PK
   SKPI=SK
   SK=S(MN,I,J,K)
   WKPI=WK
   WK=W(I,J,K)
   RHOAVE=1.0+0.5*BETA*(SK+SKPI)
   IF(I.EQ.1.OR.I.EQ.IMAX) GO TO 16
   COMPX=(U(MN,IPI,J,K)*W(IPI,J,K)-U(MN,IM1,J,K)*W(IM1,J,K))
   & *(0.5*DXINV)
   GO TO 18
16 COMPX=0.0
18 COMPY=(V(MN,I,JPI,K)*W(I,JPI,K)-V(MN,I,JM1,K)*W(I,JM1,K))
   & *(0.5*SYI*DYINV)
   COMPZ=WKPI*WKPI-WK*WK
   PK=PKPI+RHOAVE*(1.0+COMPX+COMPY)*DZ+COMPZ)
   P(I,J,K)=PK
   IF(PK.GE.0.0) GO TO 20
   KEYOUT=1
   WRITE(LW,1000)N,I,J,K
   RETURN
20 CONTINUE
30 CONTINUE
   KBOTW=KFLOOR(I,JW)
   KBOTE=KFLOOR(I,JE)
   DO 34 K=KBOTW,KMAX
34 P(I,JW-1,K)=P(I,JW,K)

```



```

DO 36 K=KBOTE,KMAX
36 P(I,JE+1,K)=P(I-JE,K)
40 CONTINUE
1000 FORMAT(/,5X,'CONGRATULATIONS BILL. YOU HAVE DISCOVERED ANTIMATTER
&AT',5X,2HN=14,5X,2HI=13,5X,2HJ=13,5X,2HK=13)
RETURN
END

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ORIGINAL PAGE IS  
OF POOR QUALITY

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SUBROUTINE CHANNEL
COMMON/DIMEN4/UC(2,12,11),WC(12,11),SC(2,12,11),PC(12,11),
C   DUCDT(12,11)
COMMON/FLOOR/KFLOOR(12,20),ZB(12,20),KFLORC(12),ZRC(12)
COMMON/PULL/X(12),Y(20),Z(11),SY(20),SYY(20),YK2,ZC(11)
COMMON/LIMITS/IMAX,IMAXM1,JMAX,JMAXM1,KMAX,KMAXM1,JWAG,KMXC,
C   KMXCM1,KCHANL
COMMON/MISCC/SCBAR,UCBAR,VISCC,DIFUSC
COMMON/VLCTYC/UCNEW,UCOLD,UCIM1,UCIP1,UCKM1,UCKP1,WCNEW,WCKM1,WCKP
C   E1,WCIM1
COMMON/STEP/N,MN,MQ,NBAR,NPRINT,NMAX,KEYOUT,LTAPE
COMMON/CODES/LW,LR,LT
C   STEP FORWARD IN TIME TO CALCULATE NEW VALUES OF UC AND SC.
C   CALL SETUPC
C   ADJUST WC FOR COMPATABILITY WITH UC.
C   CALL VOLDLC
C   RETURN
C   ENTRY PRESC1
C   UPDATE PC OVER THE FIELD.
C   CALL PRESCC
C   IF(KEYOUT.NE.0)GO TO 100
C   ALL DEPENDENT VARIABLES HAVE NOW BE COMPUTED FOR THIS TIME
C   STEP.
C   IF(N.NE.NBAR*(N/NBAR))GO TO 20
C   WRITE(LW,1000)N,SCBAR,UCBAR
C   20 IF(N.NE.NPRINT*(N/NBAR))GO TO 30
C   AN INTERMEDIATE WRITE STATEMENT COULD GO HERE.
C   30 IF(N.LT.NMAX) RETURN
C   100 WRITE(LW,1000)N,SCBAR,UCBAR
C   RETURN
C   1000 FORMAT(5X,'N=',I4,5X,'SCBAR=',IPE13.6,5X,'UCBAR=',E13.6)
C   END

```

```

SUBROUTINE SWEDGE
  LOCATE POSITION OF SALT WEDGE INTERFACE(0.5 ISOHALINE)
  COMMON/DIMEN4/UC(2,12,11),WC(12,11),SC(2,12,11),PC(12,11),
&   DUCDT(12,11)
  COMMON/FLOOR/KFLOOR(12,20),ZB(12,20),KFLORC(12),ZBC(12)
  COMMON/GRID/DX,DY,DZ,DT,DT02,DXINV,DYINV,DZINV,SYJ,SY2,SYJPI,SYJMI
  COMMON/PULL/X(12),Y(20),Z(11),SY(20),SYY(20),YK2,ZC(11)
  COMMON/LIMITS/IMAX,IMAXMI,JMAX,JMAXMI,KMAX,KMAXMI,JWAG,KMXC,
&   KMXCMI,KCHANL
  COMMON/STEP/N,MN,MO,NBAR,NPRINT,NMAX,KEYOUT,LTAPE
  COMMON/WEDGE/ZW(17)
  DO 30 I=1,IMAX
    KBOT=KFLOORC(I)
    IF(SC(MO,I,KBOT).LT.0.5)GO TO 25
    K=KFLOORC(I,JWAG)+KCHANL
    IF(SC(MO,I,K).GT.0.5) GO TO 35
    20 K=K-1
    IF(SC(MO,I,K).LT.0.5)GO TO 20
    ZW(I)=ZC(K)+(SC(MO,I,K)-0.5)/(SC(MO,I,K)-SC(MO,I,K+1))*DZ
    GO TO 30
    35 ZW(I) = ZC(K)
    GO TO 30
    25 ZW(I)=ZBC(I)
    30 CONTINUE
  RETURN
END

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SUBROUTINE SETUPC
C   VALUES ARE CALLED FROM DIMENSIONED VARIABLES AND ASSIGNED TO
C   UNDIMENSIONED VARIABLES WHICH WILL BE USED TO CALCULATE NEW
C   VALUES OF UC AND SC
COMMON/DIMEN1/U(2,12,20,11),V(2,12,20,11),W(12,20,11)
COMMON/DIMEN2/S(2,12,20,11),P(12,20,11)
COMMON/DIMEN4/UC(2,12,11),WC(12,11),SC(2,12,11),PC(12,11),
E   DUCDT(12,11)
COMMON/FLOOR/KFLOOR(12,20),ZB(12,20),KFLOORC(12),ZBC(12)
COMMON/PULL/X(12),Y(20),Z(11),SY(20),SYY(20),YK2,ZC(11)
COMMON/LIMITS/IMAX,IMAXM1,JMAX,JMAXM1,KMAX,KMAXM1,JWAG,KMXC,
E   KMXCM1,KCHANL
COMMON/GRID/DX,DY,DZ,DT,DT02,DXINV,DYINV,DZINV,SYJ,SY2,SYJP1,SYJM1
COMMON/STEP/N,MN,MC,NBAR,NPRINT,NMAX,KEYOUT,LTAPE
COMMON/UNITS/VREF,HREF,GRAV,PI,BETA,FETCH,YMAY,OMEGA,CDEPTH
COMMON/CONCC/SCNF*,SCOLD,SCIM1,SCIPI,SCKM1,SCKP1,RHO,RHOINV
COMMON/VLCTYC/UCNE*,UCOLD,UCIM1,UCIPI,UCKM1,UCKP1,WCKM1,WCKP
E   I,WCIM1
COMMON/PRESC/PCK,PCIP1,PCIM1
COMMON/TURB/COEFVH,COEFVZ,COEFDH,COEFDZ,RICH,CRICH
COMMON/LN/FUNLN1,FUNKAP
COMMON/INDEX/I,J,K
COMMON/MISCC/SCBAR,UCBAR,VISCC,DIFUSC
UCBAR=0.0
SCBAR=0.0
DO 30 I=2,IMAX
  IP1=I+1
  IM1=I-1
  KBOT=KFLOORC(I)
  KBOTP1=KBOT+1
  ZB1=ZBC(I)
  THIS IS A SERIES APPROXIMATION OF A LN FUNCTION
  ALPHA1=5.0*(ZC(KBOTP1)-ZB1)-1.0
  ALPHA2=ALPHA1*ALPHA1
  ALPHA3=ALPHA2*ALPHA1
  ALPHA4=ALPHA3*ALPHA1

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```

ALPHA5=ALPHA4*ALPHA1
FUNLN2=ALPHA1-0.5*ALPHA2+0.3333*ALPHA3-0.25*ALPHA4+0.2*ALPHA5
FUNLN=(1.0-DZ/((ZC(KBOT))-ZB1+0.5*DZ))*(FUNLN1+FUNLN2+FUNKAP))
SCOLD=SC(MO,I,KBOT)
UCOLD=UC(MO,I,KBOT)
WCNEW=WC(I,KBOT)
SCKM1=SCOLD
SCKP1=SC(MO,I,KBOTP1)
UCKP1=UC(MO,I,KBOTP1)
WCKP1=WC(I,KBOTP1)
SCIM1=SC(MO,IM1,KBOT)
UCIM1=UC(MO,IM1,KBOT)
IF (I.EG.IMAX) GO TO 4
SCIP1=SC(MO,IP1,KBOT)
UCIP1=UC(MO,IP1,KBOT)
GO TO 5
4 SCIP1=1.0
UCIP1=UCOLD
5 CONTINUE
C      A NEW VALUE OF SC AT THE BOTTOM GRID POINT IS NOW COMPUTED
CALL BTGRDC
SC(MN,I,KBOT)=SCNEW
SCBAR=ABS(SCNEW-SCOLD)+SCBAR
KCMXM1=KFLOOR(I,JWAG)+KCHANL-2
DO 10 K=KBOTP1,KCMXM1
KP1=K+1
KM1=K-1
SCKM1=SCOLD
SCOLD = SCKP1
SCKP1=SC(MO,I,KP1)
UCKM1=UCOLD
UCOLD=UCKP1
UCKP1=UC(MO,I,KP1)
WCKM1=WCNEW
WCNEW=WCKP1
WCKP1=WC(I,KP1)

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SCIM1=SC(MD,IM1,K)
UCIM1=UC(MD,IM1,K)
PCIM1=PC(IM1,K)
IF(I.EQ.IMAX)GO TO 7
SCIP1=SC(MD,IP1,K)
UCIP1=UC(MD,IP1,K)
PCIP1=PC(IP1,K)
GO TO 8
7 SCIP1=1.0
UCIP1=UCOLD
PCIP1=1.5*PC(I,K)-0.5*PCIM1
8 CONTINUE
C THE RICHARDSON NO. IS COMPUTED
DQ=ABS(UCKP1)-ABS(UCKM1)
RICH=CRICH*(SCKP1-SCKM1)/(DQ*DQ+1.0E-6)
IF(RICH.LT.0.0)RICH=0.0
RHOINV=1.0-BETA*SCOLD
NEW VALUES OF UC AND SC AT INTERIOR GRID POINTS ARE COMPUTED
CALL USNEW
SC(MN,I,K)=SCNEW
SCBAR=SCBAR+ABS(SCNEW-SCOLD)
UC(MN,I,K)=UCNEW
UCBAR=UCBAR+ABS(UCNEW-UCOLD)
10 CONTINUE
C NEW VALUE OF UC AT THE BOTTOM GRID POINT IS DETERMINED
C BY A LN CURVE FIT
UC(MN,I,KBOT)=UC(MN,I,KBOTP1)*FUNLN
C NEW VALUES OF UC AND SC JUST BELOW BAY-CHANNEL INTERFACE ARE
C COMPUTED
K=KCMXM1+1
KP1=KFLDOR(I,JWAG)
SCIM1=SC(MD,IM1,K)
UCIM1=UC(MD,IM1,K)
PCIM1=PC(IM1,K)
SCKM1=SCOLD
SCOLD=SCKP1

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```

SCKP1=S(MO,I,JWAG,KPI)
UCKM1=UCOLD
UCOLD=UCKP1
UCKP1=U(MO,I,JWAG,KPI)
WCKM1 = WCNW
WCNEW = WCKP1
WCKP1=W(I,JWAG,KPI)*S.247
IF(I.EQ.IMAX)GO TO 11
IF(KFLOOR(IP1,JWAG).LT.KPI) GO TO 13
SCIP1=SC(MO,IP1,K)
UCIP1=UC(MO,IP1,K)
PCIP1=PC(IP1,K)
GO TO 12
13 KIP1 = KFLOOR(IP1,JWAG)
SCIP1=S(MO,IP1,JWAG,KIP1)
UCIP1=U(MO,IP1,JWAG,KIP1)
PCIP1 = P(IP1,JWAG,KIP1)
GO TO 12
11 SCIP1=1.0
UCIP1=UCOLD
PCIP1=1.5*PC(I,K)-0.5*PCIM1
12 D0=ABS(UCKP1)-ABS(UCKM1)
RICH=CRICH*(SCKP1-SCKM1)/(D0*D0+1.0E-6)
IF(RICH.LT.0.0) RICH=0.0
RHOINV=1.0-BETA*SCOLD
CALL USNEW
SC(MN,I,K)=SCNEW
SCBAR=SCBAR+ARS(SCNEW-SCOLD)
UC(MN,I,K)=UCNEW
UCBAR=UCBAR+ABS(UCNEW-UCOLD)
30 CONTINUE
RETURN
END

```

```

SUBROUTINE USNEW
  THIS SUBROUTINE CALCULATE NEW VALUES OF UC AND SC
  COMMON/DIMEN4/UC(2,12,11),WC(12,11),SC(2,12,11),PC(12,11),
&    DUCDT(12,11)
  COMMON/FLOOR/KFLOOR(12,20),ZB(12,20),KFLORC(12),ZBC(12)
  COMMON/GRID/DX,DY,DZ,DT,DT02,DXINV,DYINV,DZINV,SYJ,SY2,SYJP1,SYJMI
  COMMON/VLCCTYC/UCNEW,UCOLD,UCIM1,UCIP1,UCKM1,UCKP1,WCNEM,WCKM1,WCKP
&1,WCIM1
  COMMON/CONCC/SCNEW,SCOLD,SCIM1,SCIP1,SCKM1,SCKP1,RHO,RHOINV
  COMMON/PRESC/PCK,PCIP1,PCIM1
  COMMON/TURB/COEFVH,COEFVZ,COEFDH,COEFDZ,RICH,CRICH
  COMMON/LIMITS/IMAX,IMAXM1,JMAX,JMAXM1,KMAX,KMAXM1,JWAG,KMXC,
&    KMXCM1,KCHANL
  COMMON/MISC/TOPLYR,SBAR,UBAR,VBAR,VISC,DIFFUS,PREFIX,ACCEL
  COMMON/MISCC/SCBAR,UCBAR,VISCC,DIFUSC
  COMMON/INDEX/I,J,K
  IF(UCOLD.GT.0.0) GO TO 10
  COMPU1=UCIP1*UCIP1-UCOLD*UCOLD
  COMPS1=0.5*(UCIP1+UCOLD)*(SCIP1-SCOLD)
  GO TO 15
10 COMPU1=UCOLD*UCOLD-UCIM1*UCIM1
  COMPS1=0.5*(UCOLD+UCIM1)*(SCOLD-SCIM1)
15 COMPU2=0.5*RHOINV*(PCIP1-PCIM1)
  IF(WCNEM.GT.0.0)GO TO 30
  COMPU4=UCKP1*WCKP1-UCOLD*WCNEW
  COMPS4=0.5*(WCKP1+WCNEW)*(SCKP1-SCOLD)
  GO TO 35
30 COMPU4=UCOLD*WCNEW-UCKM1*WCKM1
  COMPS4=0.5*(WCNEW+WCKM1)*(SCOLD-SCKM1)
35 CONTINUE
  NOW SOLVING THE X-MOMENTUM EQUATION.
  CALL VISC5C
  DU/DT= -(D(U*U)/DX+D(U*V)/DZ+(1.0/RHO)*DP/DX)
  +COEFVX*(DSOU/DXSQ)+COEFVZ*(DSOU/DZSQ)

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DUCODT=-DXINV*(COMPU1+COMPU2)-DZINV*CCMPU4+VISCC
UCNEW=UCOLD+(DUCODT+DUCDT(I,K))*DT02
DUCDT(I,K)=DUCODT
      NOW SOLVING THE CENSERVATION OF SALT EQUATION
40 CALL DIFSEC
DSCODT=-DXINV*COMPS1-DZINV*COMPS4+DIFUSC
SCNEW=SCOLD+DSCODT*DT*ACCEL
IF(I.EQ.IMAX) SCNEW = 1.0
RETURN
      THIS IS A SPECIAL ENTRY FOR CALCULATING SC AT THE BOTTOM GRID
      POINTS.
C      ENTRY BTGRDC
      RICH=0.0
      IF(UCOLD.GT.0.0)GO TO 45
      COMPS1=0.5*(UCIPI+UCOLD)*(SCIP1-SCOLD)
      GO TO 50
45 COMPS1=0.5*(UCOLD+UCIM1)*(SCOLD-SCIM1)
50 COMPS4 = 0.0
      GO TO 40
      END
C
C

```

```

SUBROUTINE VISCSC
COMMON/GRID/DX,DY,DZ,DT,DT02,DXINV,DYINV,DZINV,SYJ,SY2,SYJPI,SYJMI
COMMON/MISCC/SCBAR,UCBAR,VISCC,DIFUSC
COMMON/CONCC/SCNEW,SCOLD,SCIMI,SCIP1,SCKM1,SCKP1,RHQ,RHOINV
COMMON/TURB/COEFVH,COEFVZ,COEFDH,COEFDZ,RICH,CRICH
COMMON/VLCTYC/UCNEW,UCOLD,UCIMI,UCIP1,UCKM1,UCKP1,WCNEW,WCKM1,WCKP
&1,WCIMI
      C    EDDY VISCOSITY TERM FOR X-MOMENTUM EQUATION IS CALCULATED
      DAMPV=1.0/SQRT(1.0+10.0*RICH)
      TWOUC=UCOLD+UCOLD
      XCOMP=DXINV*DXINV*(UCIP1-TWOUC+UCIMI)
      ZCOMP=DZINV*(ZINV*(UCKP1-TWOUC+UCKM1)
      VISCC=COEFVH*XCOMP+COEFVZ*DAMPV*ZCOMP
      RETURN

```

```

      C    ENTRY DIFSEC

```

```

      C    EDDY DIFFUSION TERM FOR SALT CONSERVATION EQUATIONS IS CALCULA

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```

      C    TED.

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      DAMPD=1.0/(1.0+3.333*RICH)**1.5

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      TWOSC=SCOLD+SCOLD

```

```

      XCOMP=DXINV*DXINV*(SCIP1-TWOSC+SCIMI)

```

```

      ZCOMP=DZINV*DZINV*(SCKP1-TWOSC+SCKM1)

```

```

      DIFUSC=COEFDH*XCOMP+COEFDZ*DAMPD*ZCOMP

```

```

      RETURN

```

```

      END

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SUBROUTINE VOLDLC
COMMON/DIMEN4/UC(2,12,11),WC(12,11),SC(2,12,11),PC(12,11),
5   DUCDT(12,11)
COMMON/FLOOR/KFLOOR(12,20),ZB(12,20),KFLORC(12),ZBC(12)
COMMON/PULL/X(12),Y(20),Z(11),SY(20),YY(20),YK2,ZC(11)
COMMON/LIMITS/IMAX,IMAXM1,JMAX,JMAXM1,KMAX,KMAXM1,JWAG,KMXC,
5   KMXCM1,KCHANL
COMMON/GRID/DX,DY,DZ,DT,DT02,DXINV,DYINV,DZINV,SYJ,SY2,SYJP1,SYJM1
COMMON/STEP/N,MN,MO,NBAR,NPRINT,NMAX,KEYOUT,LTAPE
COMMON/CODES/LW,LR,LT
DO 30 I=2,IMAXM1
IM1=I-1
IP1=I+1
KBOT=KFLOOR(I)
KBOTP1=KBOT+1
K=KBOT
UC1=UC(MN,I,K)
UCIM1=UC(MN,IM1,K)
UCIP1=UC(MN,IP1,K)
ZC1=ZC(K)
ZBC1=ZBC(I)
ZBCIM=0.5*(ZBC1+ZBC(IM1))
ZBCIP=0.5*(ZBC1+ZBC(IP1))
UCIN=0.25*(UC1+UCIM1)
UCOUT=0.25*(UC1+UCIP1)
WCNEW=DXINV*(UCIN*(ZC1-ZBCIM)-UCOUT*(ZC1-ZBCIP))
WC(I,KBOT)=WCNEW
KKMAX=KFLOOR(I,JWAG)+KCHANL-1
DO 10 K=KBOTP1,KKMAX
KM1=K-1
UCIMKM=UCIM1
UCIM1=UC(MN,IM1,K)
UCIPKM=UCIP1
UCIP1=UC(MN,IP1,K)
UCIN=0.25*(UCIM1+UCIMKM)
UCOUT=0.25*(UCIP1+UCIPKM)

```

```

WCIN=0.50*WCNEW+0.25*(WC(IM1,KM1)+WC(IP1,KM1))
WCNEW=WCIN-(UCOUT-UCIN)*DXINV*DZ
10 WC(I,K)=WCNEW
30 CONTINUE
   KKMAX=KFLOOR(1,JWAG)+KCHANL-1
   KBOT=KFLOORC(1)
   DO 50 K=KBOT,KKMAX
     WC(1,K)=WC(2,K)
     KKMAX=KFLOOR(IMAX,JWAG)+KCHANL-1
     KBOT=KFLOORC(IMAX)
     DO 60 K=KBOT,KKMAX
       WC(IMAX,K)=WC(IMAXM1,K)
     RETURN
   END

```

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SUBROUTINE PRESSC
  THIS SUBROUTINE CALCULATES THE PRESSURE.
  COMMON/DIMEN1/U(2,12,20,11),V(2,12,20,11),W(12,20,11)
  COMMON/DIMEN2/S(2,12,20,11),P(12,20,11)
  COMMON/DIMEN4/UC(2,12,11),WC(:2,11),SC(2,12,11),PC(12,11),
&   DUCDT(12,11)
  COMMON/FLOOR/KFLOOR(12,20),ZB(12,20),KFLOORC(12),ZBC(12)
  COMMON/LIMITS/IMAX,IMAXM1,JMAX,JMAXM1,KMAX,KMAXM1,JWAG,KMXC,
&   KMXXM1,KCHANL
  COMMON/GRID/DX,DY,DZ,DT,DT02,DXINV,DYINV,DZINV,SYJ,SY2,SYJPI,SYJM1
  COMMON/STEP/N,MN,MC,NBAR,NPRINT,NMAX,KEYOUT,LTAPE
  COMMON/UNITS/VREF,HREF,GRAV,PI,BETA,FETCH,YMAX,CMEGA,CDEPTH
  COMMON/CODES/LW,LR,LT
  DO 40 I=1,IMAX
    IM1=I-1
    IP1=I+1
    KC=KFLOOR(I,JWAG)+KCHANL-1
    SCK=SC(MN,I,KC)
    RHO=1.0+BETA*SCK
    IF(I.EQ.1.OR.I.EQ.IMAX) GO TO 12
    COMPX=(UC(MN,IP1,KC)*WC(IP1,KC)-UC(MN,IM1,KC)*WC(IM1,KC))
&   *(0.5*DXINV)
    GO TO 14
  12 COMPX=0.0
  14 KBOT=KFLOOR(I,JWAG)
    PCK=P(I,JWAG,KBOT)+RHO*(1.0+COMPX)*DZ
    PC(I,KC)=PCK
    WCK=WC(I,KC)
    KBOT=KFLOORC(I)
    KKMAX=KC-KBOT
    DO 20 KK=1,KKMAX
      K=KC-KK
      PCKP1=PCK
      SCKP1=SCK
      SCK=SC(MN,I,K)
      WCKP1=WCK

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WCK=WC(I,K)
RHOAVE=1.0+0.5*BETA*(SCK+SCKP1)
IF(I.EQ.1.OR.I.EQ.IMAX)GO TO 16
COMPX=(UC(MN,IP1,K)*WC(IP1,K)-UC(MN,IM1,K)*WC(IM1,K))*{0.5*DXINV)
GO TO 18
16 COMPX=0.0
18 COMPZ=WCKP1*WCKP1-WCK*WCK
PCK=PCKP1+RHOAVE*((1.0+COMPX)*DZ+COMPZ)
PC(I,K)=PCK
IF(PCK.GE.0.0)GO TO 20
KEYOUT=1
WRITE(LW,1000)N,I,K
RETURN
20 CONTINUE
40 CONTINUE
RETURN
1000 FORMAT(/,5X,'CONGRATULATIONS FRED.YOU HAVE DISCOVERED ANTIMATTER
      & AT',5X,'N=',I4,5X,'I=',I3,5X,'K=')
      END

```

BLOCK DATA

C  
C  
C

VARIOUS CONSTANTS ARE DEFINED

COMMON/UNITS/VREF,HREF,GRAV,PI,BETA,FETCH,YMAX,OMEGA,CDEPTH  
COMMON/STEP/N,MN,MO,NBAR,NPRINT,NMAX,KEYOUT,LT APE  
COMMON/CODES/LW,LR,LT

C LW,LR,LT ARE THE LOGICAL INPUT/OUTPUT UNIT CODES FOR WRITING, READING  
C AND USING A TAPE.

DATA LW,LR,LT/6,5,3/

DATA N,KEYOUT,MN,MO,NBAR/0,0,1,2,1/

DATA GRAV,PI,OMEGA/9.790,3.14159,7.29E-5/  
END

DATA

1	12	20	9	10	11
1100	1100		1		
50.586	26.313				
43.36	47.066				
0.5	1.4	5.0			
9.0	22.0	0.0			
10.0	0.4				
450.0	200.0	30.7			
12.2	3.0				
22					
0.0	6.0	-0.1			
1.3	5.9	-1.35			
2.6	5.85	-1.45			
3.9	6.2	-1.4			
5.2	6.0	-1.65			
6.5	6.35	-2.5			
7.8	6.4	-3.0			
9.1	5.9	-3.15			
10.4	5.4	-4.2			
11.7	4.25	-4.35			
13.0	5.0	-4.4			
14.3	5.2	-4.8			
15.6	5.4	-4.6			
16.9	6.5	-4.55			
18.2	8.25	-4.45			
19.5	9.8	-4.85			
20.8	10.9	-5.4			
22.1	13.1	-5.35			
23.4	14.0	-5.0			
24.7	14.2	-4.4			
26.0	11.2	-3.8			
27.3	0.5	-3.2			
1853.0					
-0.1	0.1	9.14	0.335	10.0	

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1.1	1.35	8.53	0.213	13.0
4.4	4.63	6.10	0.168	17.0
5.5	5.8	7.92	0.229	18.0